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Agricultural
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Service

Northern
Plains Area

Natural Resources Research Center

1993 Report

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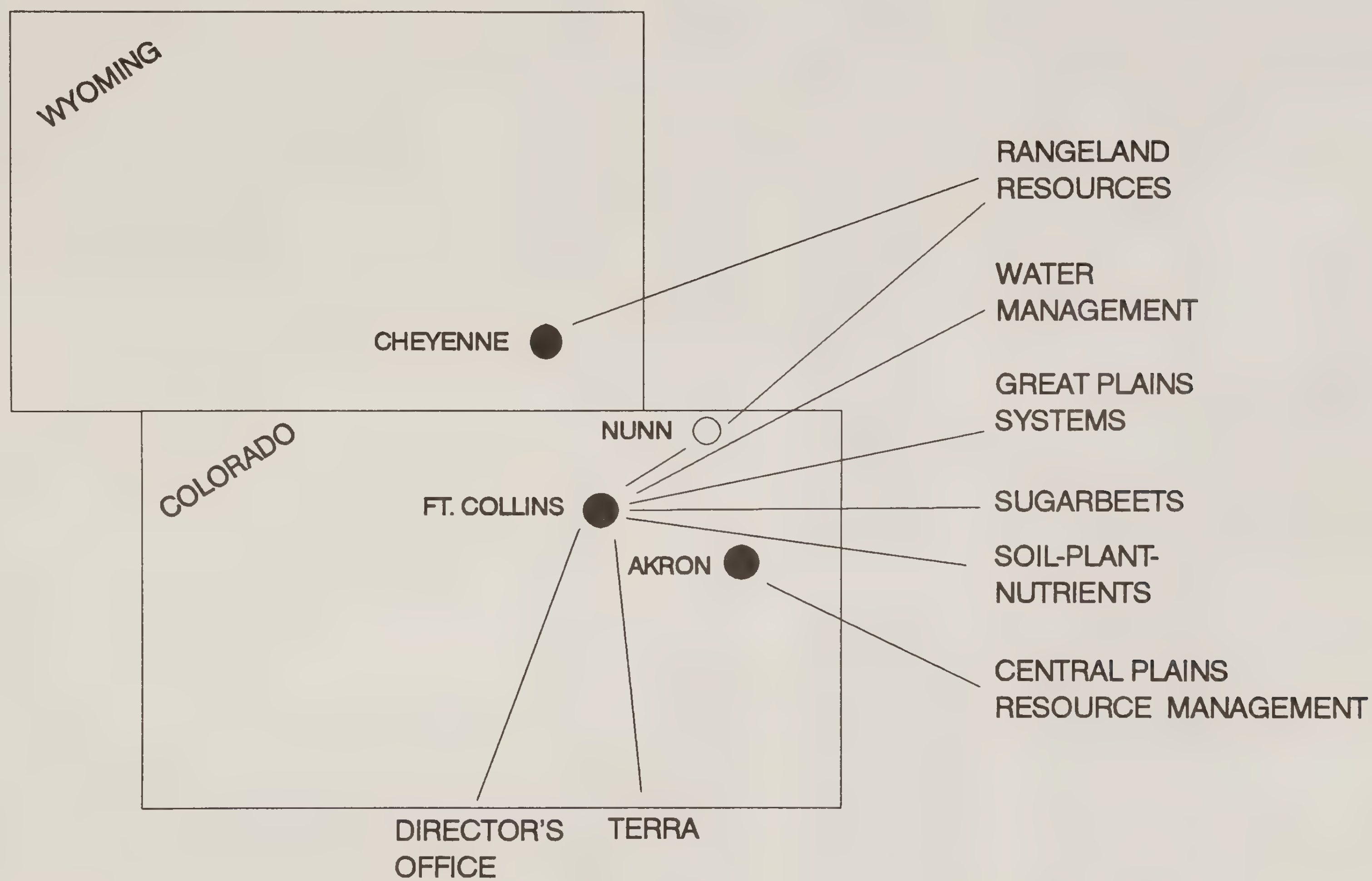
NATURAL RESOURCES RESEARCH CENTER



INTRODUCTION

James R. Welsh

The Natural Resources Research Center is a coordinated structure of research units with strong emphasis on quality products and customer satisfaction. This report summarizes Center research production for CY 1993. Material is arranged by research unit with appropriate contact information to encourage information exchange and cooperation across the total scientific community. The scientific publications, presentations, awards and recognitions, technology transfer and emerging partnerships with public and private sector organizations demonstrate outstanding performance by Center research scientists and staff.

This year has been one of emerging issues related to agriculture. In particular, environmental concerns and natural resource protection have received increasing national priority and attention. The NRRC recognizes this trend, primarily through interaction with customers from all backgrounds of life. In response, program thrusts are continually being updated to address both contemporary and forward looking societal needs.

The Center has embraced Total Quality Management as a way of conducting daily business. 1993 was a year of growth and learning in TQM. The Center is now ready to launch a major thrust of TQM application to production of research products for external customer satisfaction.

We hope you will find this report valuable. You are encouraged to contact any of the NRRC scientists and staff for further information.

NRRC Staff - 1993

James Welsh, Center Director
Olga Lee, Secretary
Ernest Affa, Facilities Manager

Steve Rapp, Custodial Maintenance
Oliver Mayhan, Prev. Maint. Tech.
Gilbert Naranjo, Minor Maint. Tech.

	Central Plains Resources Management Research Unit	Great Plains Systems Research Unit	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Terrestrial Ecosystems Regional Research and Analysis	Water Management Research Unit
Research Scientists	Ardell Halvorson, RL Randy Anderson Rudy Bowman Steven Hinkle David Nielsen Merle Vigil	Lajpat Ahuja, RL Jon Hanson Gregory McMaster Marvin Shaffer	Gerald Schuman, RL Terrence Booth Gary Frasier Richard Hart Jack Morgan Charley Townsend	Ronald Follett, RL William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter	Earl Ruppel, RL Susan Martin Leonard Panella	Donn DeCoursey Brenda Faber Doug Fox Ray Watts Bob Woodmansee	Harold Duke, RL Walter Bausch Gerald Buchleiter Dale Heermann Edward Schweizer Roger Smith
Support Scientists	William Beard Curtis Reule	Patricia Bartling Mary Brodahl Gale Dunn Virginia Ferreira Harriet Havis	Daniel LeCain Jean Reeder Ernest Taylor	Robert Lober William O'Dean	Andrew Lenssen	Bill Wallace Virginia Ferreira	Richard Miskimins Kristine Stahl
Post Docs		Robert Aiken Barry Baker Joseph Benjamin Romelito Lapitan Bruce Wylie	John Reed	Jorge Delgado Peter Scharf			Scott Howarth Lori Wiles
Research Support Staff	Lynne Bixler Robert Florian Donna Fritzler Stephanie Hill Herman Horner Hubert Lagae Arnold Page Gene Uhler	William Dailey Debora Edmunds Terry Leonard Michael Murphy Daniel Palic Kenneth Rojas Lucretia Sherrod	Willard Ackerman Mary Ashby Leon Chea Stanley Clapp Pamela Freeman Larry Griffith Roger Kerbs Chris Mahelona Matt Mortenson Dennis Mueller James Pry Jeffrey Thomas Barry Weaver	Charles Andre Edward Buenger Susan Crookall Cathy Krumwiede Margarita Licha Robin Montenieri Elizabeth Pruessner Mary Smith	Mary Hjort Mary McClintock Patricia Noble Les Shader Johnny Thomas John Vasquez	Saneta Gavette Jeffery Lundstrom Sandy Maple Jeff Miller	Douglas Barlin Edward Barry Theodore Bernard Michael Blue Brad Carnahan Kirsten Close Mark Collins Monty Dickson Elizabeth Dormer Dave Engel Chris Iremonger Charles Newcomb Jeff Ohlsen Dean Santisteven Chris Toomer Ken Webster Faisal Zeineldin Yousheng Zheng Stuart van Greuningen
Administrative Support Staff	Ginger Allen Llewellyn Bass Linda Pieper	Virginia Krug Marlene Miller Monique Wilson	Marcella Currie-Gross Ann Heckart Pam Kerbs Kathleen Peterson	Stacey Wilkins	Marcella Currie-Gross	Ann Millard	Nora Kohuth Maxine McCauley
Visiting Scientists/ Cooperative Staff	Wayne Shawcroft Scott Armstrong Mike Koch	Jacob Dane Hamid Farrahani Karen Johnsen Dennis Linden Qingli Ma Keith Paustian		Gerald Livingston			

AWARDS AND RECOGNITION - 1993

Employee	Award(s)/Recognition Received
Laj Ahuja	· Technical Editor, SSSAJ 1994-1996 · Chair, GPAC Task Force on Computer Applications in Water Management
Rob Aiken	· Recipient of the 1993 Editor's Citation for Excellence in Manuscript Review, *Journal of Environmental Quality* · Certificate of Appreciation for exceptional efforts in Unit's field research
Pat Bartling	· Certificate of Appreciation for exceptional efforts and dedication to GPFARM and excellent performance on Unit's Social Committee and Purchasing Task Team
Walter Bausch	· Program Chair, International Evapotanspiration and Irrigation Scheduling Conference, Nov 1996 (ASAE, Irrig Assoc, ICID) · Chair, ASAE Evaporation Committee (SW-213) · ASAE Paper Award Honorable Mention: Bausch, W.C. and Bernard, T.M. 1992. Spatial averaging Bowen ratio system: Description and lysimeter comparison. Trans of the ASAE 35(1):121-128
Ted Bernard	· ASAE Paper Award Honorable Mention: Bausch, W.C. and Bernard, T.M. 1992. Spatial averaging Bowen ratio system: Description and lysimeter comparison. Trans of the ASAE 35(1):121-128
Terrence Booth	· Chair-elect, W-168: Seed Biology and Technology Investigations · President-elect, Wyoming Section Society for Range Management
Mary Brodahl	· Certificate of Appreciation for exceptional efforts in Unit's field research
Edward Buenger	· Cash award. For exemplary effort in establishing electrical supplies and bench space for the new Carlo Erba and Tracermass analyzers; in maintaining the electronic and vacuum systems of 3 mass spectrometers and gas systems and sample handlers of two automated nitrogen analyzers.
Bill Dailey	· Certificate of Merit (cash award) for exceptional efforts in wiring the Federal Building for networking computers · Certificate of Merit (cash award) for exceptional efforts in bringing the Internet computer system to the Federal Building
Harold Duke	· Chair, ASAE Refereed Publications Committee (P-511)
Gale Dunn	· Certificate of Appreciation for exceptional efforts in Unit's safety committee · Certificate of Appreciation for exceptional efforts in Unit's field research · Certificate of Appreciation from Larimer County Employment and Training Services Summer Youth Program
Debora Edmunds	· Certificate of Appreciation for exceptional efforts and dedication to GPFARM and excellent performance on Unit's Social Committee and Purchasing Task Team

Employee	Award(s)/Recognition Received
Virginia Ferreira	· Appointed to NPA Workforce Diversity Task Force and detailed to Area Office for 1 year to provide Task Force leadership · Certificate of Appreciation for exceptional efforts in Unit's field research
Ronald Follett	· 1993 President, Soil and Water Conservation Service, Colorado Chapter
Ardell Halvorson	· Commendation Award from Soil and Water Conservation Society · Chapter Commendation Award from Colorado Chapter of Soil and Water Conservation Society · Certificate of Appreciation from Technology Resources Integrated Management (TRIM)
Jon Hanson	· Certificate of Appreciation for exceptional efforts in responding to MSEA customer needs
Harriet Havis	· Certificate of merit (cash award) for exceptional efforts in helping with the move of fellow employees to new offices
Dale Heermann	· ARS Liaison to SCS Technical Information Services Division · Chair, ASAE Marketing Emphasis Group (E-10/3) · Chair, Irrigation Association Awards Committee · Fellow, Amer. Soc. Agricultural Engineers
Steven Hinkle	· Service Recognition Award from Colorado Conservation Tillage Association
Scott Howarth	· Vice-Chair, ASAE Flexible Automation and Robotics Committee (IET-218)
Karen Johnsen	· Certificate of Appreciation for exceptional efforts in responding to MSEA customer needs
Olga Lee	· Certificate of Merit (cash award). In recognition of outstanding performance and initiative as secretary for the Natural Resources Research Center
Terry Leonard	· Certificate of Merit (cash award). For showing exceptional responsibility and performance in designing, installing, and maintaining field instruments, ensuring safe and legal handling of radioactive materials, and maintaining the Unit's vehicles. · Certificate of Appreciation for exceptional efforts in Unit's field research · Certificate of Appreciation for exceptional efforts in Unit's Radiation Safety
Susan Martin	· Editor-in-Chief, *J. Sugar Beet Res.* (93-95) · Chair, Phytochemical Sect., Botanical Soc. of America (94) · Vice President (President-Elect), American Soc. of Sugar Beet Technologists (93-95)
Greg McMaster	· Consultant in South Africa on SHOOTGRO Model · Certificate of Appreciation for exceptional efforts in Unit's field research
Arvin Mosier	· Fellow, Soil Science Society of America

Employee	Award(s)/Recognition Received
Mike Murphy	· Certificate of Merit (cash award) for exceptional efforts in helping with the move of fellow employees to new offices · Certificate of Appreciation for exceptional efforts in Unit's field research · Certificate of Appreciation from Larimer County Employment and Training Services Summer Youth Program
Daniel Palic	· Certificate of Appreciation for exceptional efforts in Unit's field research
Lee Panella	· Invited to chair panel on North America *Beta* Genetic Resources at the World *Beta* Network Conference, Aug 1993
Curtis Reule	· Northern Plains Area Safety Performer of the Year Award
Ken Rojas	· Certificate of Appreciation for exceptional efforts in responding to MSEA customer needs
Earl Ruppel	· Invited member of Sugarbeet Rhizomania Task Force in Colorado
Gerald Schuman	· Fellow Award, Soil Science Society of America, November 9, 1993, Cincinnati, OH · Outstanding Range Man Award, Wyoming Section, Society for Range Management, November 19, 1994, Cody, WY · President, American Society for Surface Mining and Reclamation, 1993 · Editorial Board, Journal of Soil and Water Conservation
Edward Schweizer	· Editorial Board, Reviews in Weed Science · Fellow and Honorary Member, Weed Science Society of America
Marvin Shaffer	· Recognition and promotion for work performed on NLEAP
Roger Smith	· Editorial Board, Geographical Abstracts: Physical Geography · Joint Editor, Modeling of Geo-biosphere Processes
James Welsh	· Awarded membership in the Society of Centennial Alumni at Montana State University
Lori Wiles	· 1993 Outstanding paper in Weed Science: Wiles, L.J., Wilkerson, G.G., Gold, H.J., and Coble, H.D. 1992. Modeling weed distribution for improved postemergence control decisions. Weed Sci. 40:546-553. · Chair, Weed Biology and Ecology Section, Weed Science Society of America
Bruce Wylie	· Certificate of Appreciation for exceptional efforts in water quality problems of the South Platte Valley

PROGRESS REPORTS

NATURAL RESOURCES RESEARCH CENTER

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MISSION STATEMENT

Promote and coordinate cooperative research activities among Center research units; serve as an advocate and solicit funding and support for priority research efforts identified by Center units and ARS; and facilitate communications and interaction among research programs and with customers locally, regionally and nationally.

TECHNOLOGY TRANSFER - 1993

Natural Resources Research Center

1. The Technology Resource Integrated Management (TRIM) project is headquartered with the Extension Service in Sterling, Colorado. Success has been achieved in enrolling project producer-cooperators and developing information background on each producer's operation. Several resource teams have provided valuable research information to producers on specific topics for improved economic returns.

2. The NRRC has encouraged the investigation of information delivery by satellite through systems such as the Data Transmission Network (DTN).

3. Two articles entitled "Getting Research to Users--A Coordinated Approach" and "Conserving the Great Plains for All" appeared in the USDA-ARS Agricultural Research magazine. A TV film clip was produced in cooperation with a local TV station to describe ARS programs impacting Colorado and Fort Collins.

4. The Center provides an important link to other agencies and organizations. These include the Great Plains Agriculture Council, Colorado State University, the Sustainable Agriculture program, the Colorado Department of Agriculture, the Soil Conservation Service, the Irrigation Association and the Colorado Conservation Tillage Association. The NRRC represents all unit programs in these contacts. Ideas and advice on program priorities and direction are actively solicited.

NRRC PROGRESS REPORT

James R. Welsh
Natural Resources Research Center

The Natural Resources Research Center (NRRC) Director's Office promotes and coordinates research activities between individuals and Units within the NRRC, the Agricultural Research Service (ARS), and other public agencies and institutions. A critical part of the coordination activity rests with the Board of Directors for the Center made up of Unit Research Leaders (RLs). Through its monthly meetings, the Board considers issues and programs to receive attention throughout the year. The following items summarize NRRC projects and activities for 1993:

PROGRAM COORDINATION: Meetings were held on Nitrogen Management and Groundwater Quality between NRRC Units and CSU scientists. Several projects were identified and initiated. Two outside grants were obtained to provide additional support for this effort.

The Great Plains Framework for Agricultural Resource Management (GPFARM) decision support system project was reviewed by the National Program Staff (NPS). Discussions between National Program Leaders (NPLs), the Great Plains Systems Research (GPSR) Unit, and CSU resulted in the establishment of a research scientist position to head this program.

A series of workshops was held on the Weed Management Modeling Project and the Decision Support Systems efforts with CSU. Approval of a permanent scientist position to lead the weed management modeling activity resulted from the coordinated effort.

The ARS/SCS Research Committee made up of Colorado SCS program leaders and NRRC Research Leaders identified high-priority research needed to meet farm plan and grower requirements. Research programs were developed to answer several high-priority questions. The Committee meets twice annually to review current activities and future research priority needs.

TOTAL QUALITY MANAGEMENT: In 1993, Total Quality Management (TQM) became embedded in the NRRC as a way of doing business to ensure quality products and service to our customers. All NRRC staff participated in two Center-wide workshops: "Introduction to TQM" and "Team Building/Tools and Techniques." The NRRC Board approved the formation of an NRRC TQM Council. The Council will develop TQM plans and processes and identify potential Center-wide projects. The Board unanimously approved the Council Charter and established specific lines of communications to foster teamwork between the Board and the Council. Council projects in process include: procurement, e-mail, a Center Scientific Exchange Day, and a Center-wide newsletter. E-mail in now being used Center-wide as a standard communication mechanism. Teams have been formed to address specific issues within each Research Unit. The Center Director has served as facilitator for Area-wide TQM projects. These include the Federal Information Processing System (FIPS) Automated Data Processing (ADP) Technical Approval Project and the Evaluation of Product and Service (Measuring Productivity) Team. A facilitator training workshop is planned for early 1994.

TRAINING PROGRAMS: The NRRC conducted a series of Statistical Analysis System (SAS) sessions, under the direction of Dr. Gary Richardson. All sessions were fully subscribed and requests for additional sessions have been received. The Crops Research Laboratory (CRL) made a decision to move completely to electronic mail (E-mail) as a common mode of communication. Training sessions on the use of Popmail and E-mail were held for all CRL personnel. Nearly all CRL personnel use E-mail regularly. All training sessions with hands-on learning were held in the new computer training center.

COMMUNICATIONS: The NRRC TQM Council's E-mail Project Team established the goal of having all NRRC staff on E-mail, with Internet access. This project will be completed in 1994. Most Council and Unit TQM teams are using E-mail and list-servers efficiently and effectively. Dramatic progress has been made in the use of electronic communications in 1993.

FACILITIES AND EQUIPMENT: Space remodeling and expansion were completed for the Great Plains Systems Unit. HVAC and chiller projects were initiated for the Soil-Plant-Nutrient Unit. A 40' x 68' building was moved from the CSU Agronomy farm to the Central Plains Experimental Range (CPER) station. Major boiler retrofitting and construction of a new steam aeration system for soil treatment were completed in the Crops Research Laboratory (CRL). The cesium source and perimeter fence has been removed from the CPER. Labs in the CRL were converted from computer use to biotechnology.

CUSTOMER INTERACTION: The NRRC actively participates with the liaison committees for the Central Plains Resources Management Research Unit, the Great Plains Systems Research Unit, and the Rangelands Resources Research Unit. In each case, customers are solicited for program priority setting and evaluation. The NRRC Director was the invited commencement speaker for the December 1993 College of Agriculture graduation ceremonies.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

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MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation/preservation.

Organizational Goals

1. Conduct research to enhance the economic and environmental well-being of Central Great Plains agriculture within a work environment conducive to client and personnel responsiveness.

2. Improve the quality of customer services and products, such as better and more timely popular and scientific publications and greater responsiveness to the needs of the scientific, agribusiness, and farming communities.

3. Provide a quality work environment for our employees.

4. Promote communications and teamwork by regular meetings and discussions.

5. Develop the skills and abilities of all employees through appropriate training in and out of the work environment.

6. Enhance the quality of work life by maintaining and enhancing self-confidence and self-esteem of co-workers.

TECHNOLOGY TRANSFER - 1993

Central Plains Resources Management Research Unit

1. The entire staff participated in a Station Field Day held on June 21, 1993 with approximately 200 farmers, ranchers, agricultural business, bankers, environmentalists, SCS, University, and other interested persons present.

2. The Scientists in the research unit are actively participating in the TRIM (Technology Resource Integrated Management) program with Colorado State University Cooperative Extension Service which is designed to enhance technology transfer from ARS and Experiment Station research to the farmer/rancher.

3. Ardell Halvorson, Randy Anderson, Rudy Bowman, and Merle Vigil continue to work with the Golden Plains Maximum Economic Yield (MEY) Club to transfer research technology to a group of very progressive farmers in the Akron area. This group of farmers is applying the results of current research being conducted at the USDA-ARS Central Great Plains Research Station.

4. Ardell Halvorson, Steven Hinkle, and David Nielsen have worked very closely with the Colorado Conservation Tillage Association (CCTA) to transfer research technology to farmers in Colorado, Kansas, and Nebraska. Dr. Halvorson is currently serving and Dr. Hinkle served on the Board of Directors of CCTA. Drs. Hinkle and Nielsen have served as editors for the CCTA Newsletter.

5. Ardell Halvorson and Randy Anderson have been working very closely with the Eastern Colorado Range Station at Akron to develop any integrated crop-livestock farming/ranching system for the Range Station. More intensive crop rotations that include forages are being implemented to replace the winter wheat-fallow system used in the past. The results of the USDA-ARS alternative crop rotations study at the Central Great Plains Research Station are being used to design the integrated crop-livestock system.

6. The Scientists at the location have participated in numerous tours of the Stations research plots and facilities and farmer informational meetings during the past year. These have been very effective for technology transfer. In addition, the staff has worked closely with the Soil Conservation Service in providing needed information.

POPULATION THRESHOLDS FOR JOINTED GOATGRASS AND VOLUNTEER RYE IN WINTER WHEAT

R. Anderson, D. Lyon, G. Wicks, S. Miller, P. Stahlman, and P. Westra
USDA-ARS, Univ. Neb, Univ. Wyo, KSU, and CSU
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00D

PROBLEM: Jointed goatgrass and volunteer rye infest winter wheat in the Central Great Plains, resulting in significant yield losses. Extensive herbicide screening research is being conducted in this region to find suitable herbicides for controlling these species in winter wheat. Also, developing a winter wheat cultivar tolerant to herbicides active on grass weeds is being explored. If this research thrust is successful, it would be appropriate to know the economic threshold for each species so that producers could determine if and when to use herbicides. Research exploring the use of mowing for reducing the future soil seed bank has also demonstrated the effectiveness of this control strategy. The threshold equations could be used to guide management decisions with mowing infested wheat for forage.

The objective of this study is to develop yield loss regression equations based on plant population for jointed goatgrass and volunteer rye in winter wheat.

APPROACH: This study was established in winter wheat, following the conventional practices for the region of each cooperator. At the Akron site, Tam 107 was planted at 45 kg/ha with a hoe-drill in 30 cm row spacing. The planting date was Sep. 18, and nitrogen was applied at 65 kg/ha 10 days after planting. The site was in a stubble mulch fallow system, where sweep plowing and rod-weeding controlled weeds during fallow. The soil type is a Rago silt loam.

Jointed goatgrass and volunteer rye were broadcast in separate plots at 5, 10, 25, and 50 plants/m^2 and incorporated with the mulch treader before planting wheat. Initial plot size was 3 m by 3 m. During the spring, two 1 m by 1 m subplots were designated for treatment analysis. The experimental design was a randomized complete block with 4 replications.

Data goals include: 1) approximate date of weed emergence in relation to winter wheat emergence; 2) weed density counts 6 weeks after planting and before April 1; 3) date of flowering for winter wheat, jointed goatgrass, and volunteer rye; 4) winter wheat grain yields from two subplots; 5) weed seed contribution to dockage and seed bank population from 1 subplot; and 6) individual plant seed production by weed species (select up to 6 plants per subplot) to supply data for modelers in determining the economic optimal threshold level. Weather data collected will include monthly rainfall during the study and long-term average for each site.

Yield loss data will be used to develop regional regression equations for predicting the economic population threshold for each species.

FINDINGS: This reports summarizes the data from the Akron site only.

Jointed goatgrass: Within a range of 0 to 18 jointed goatgrass plants/m^2, the yield loss equation ($Y = 0.8 + 1.1X$, $r^2 = 0.49$) indicated that each jointed goatgrass plant reduced yields by 1.1%, with 18 plants/m^2 reducing yields 21%. Jointed goatgrass emerged within 14 days of winter wheat. These results agree with a previous study conducted at Akron, which showed that 18 jointed goatgrass plants/m^2 caused 23% yield loss when emerging 14 days after winter wheat.

Volunteer rye: The yield loss equation for volunteer rye ($Y = -0.4 + 2.9X$, $r^2 = 0.88$) showed that for each volunteer rye plant/m^2, winter wheat grain yields decreased by 2.9%. Comparing the two species for effect on winter wheat grain yield shows that volunteer rye is 2.6 times more damaging than jointed goatgrass.

Similar trends in winter wheat response to these species occurred at the other sites in Kansas and Wyoming.

INTERPRETATION: Based on this study and previous research with downy brome, these species can be ranked with a competitive index: if yield loss per plant of downy brome = 1.0, then jointed goatgrass = 2.8, and volunteer rye = 7.3. With volunteer rye especially, these data show that even low populations can cause major yield loss, as only 3 volunteer rye plants/m^2 would cause 8% yield loss.

FUTURE PLANS: This study is being repeated in 1993-1994. At the conclusion of this study, a regional publication will be developed to guide producer decisions in controlling these species. This team is also planning research to explore the effect of winter wheat density and planting date on jointed goatgrass interference. This team will be developing a training session for producers, where present management strategies will be explained.

EFFECT OF CROPPING ROTATIONS AND TILLAGE ON EMERGENCE OF JOINTED GOATGRASS AND DOWNY BROME

R.L. Anderson and D.C. Nielsen
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00D

PROBLEM: In the Plains region, jointed goatgrass and downy brome are two difficult-to-control weeds infesting winter wheat, and their seed persists in soil for up to five years. Rotations which include summer annual crops are used by producers to minimize interference of jointed goatgrass and downy brome in winter wheat by decreasing the weed seed population in soil. The weed seed population decreases because the seed germinates or decays naturally before the winter wheat is planted. Rotations lengthens the time before the next winter wheat crop, thus allowing more seed loss in soil. Success in reducing the weed seed population would be enhanced if producers could hasten germination of weed seeds in the soil during non-wheat years.

The choice of summer annual crop may affect the germination of these winter annual weeds in the fall of the crop season. For example, proso millet and sorghum canopies inhibit volunteer winter wheat emergence. However, emergence within a corn canopy is not reduced to the same extent, indicating that use of corn rather than proso millet or sorghum in the rotation may increase the rate of weed seed decline by germination. If summer annual crop canopies affect germination of jointed goatgrass and downy brome, then producers could target their severely-infested sites for germination-enhancing canopies. Also, combining one timely tillage operation (to stimulate germination yet not bury the residue) with a selected crop canopy may greatly enhance weed seed germination without deleteriously affecting crop growth.

The objectives for this study are: 1) evaluate the effect of crop rotations and tillage on the longevity of jointed goatgrass and downy brome seed in the soil; and 2) determine the effect of summer annual crop canopies on fall emergence of jointed goatgrass and downy brome.

APPROACH: Four crop canopy choices are being evaluated within 3-, 4-, and 5-year rotations. The rotations are wheat-canopy choices-fallow, wheat-corn-canopy choices-fallow, and wheat-corn-oats for forage-canopy choices-fallow. Two tillage systems are being compared: no-till and reduced till (one sweep plow operation in the fall). The canopy and tillage treatments are arranged as a two-way factorial in a randomized complete block design with three replications. The rotations are arranged in a split-block design. Within each plot, 1 m^2 was designated and 200 seeds each of jointed goatgrass and downy brome spread on the soil surface. The tillage operation occurred after seed spreading. Winter wheat was present within the local soil seed bank, but jointed goatgrass and downy brome had not been observed previously at this site.

Seedling emergence is being recorded weekly for each 1 m^2 site for the duration of the study (5 years). There are 24 sites for each rotation (3 replications for each of the 4 canopies and 2 tillage treatments) and 3 rotations, resulting in 72 sites. After completion of the canopy

choice cropping season within each rotation, winter wheat will be planted the following September. Weed seedling counts for each site will be recorded within wheat and soil samples will be collected after wheat harvest to estimate the remaining weed seed population in the soil.

Within each canopy in 1993, 25 seeds of each species were planted in one meter rows on Aug. 15, Sep. 1, Sep. 15, Oct. 1, Oct. 15, and Nov. 1. Simulated rainfall at 6 mm was applied after planting. Seedling counts were recorded 21 days later.

Soil temperature is being monitored continuously with thermocouple arrays at 2.5 cm. Soil water levels are being determined with time-domain reflectometry for the top 5 cm. Standard weed control practices are being followed for each crop.

FINDINGS: Crop canopy microclimate affected the emergence of jointed goatgrass and downy brome. For every seedling (of either species) emerging in proso millet, 2.2, 2.1, and 2.2 seedlings emerged in corn, barley, and fallow, respectively. Precipitation during the fall of 1993 was higher than normal, with > 9 cm received in October. This high level of precipitation may have ameliorated the canopy effect on seedling emergence, as the long-term data indicates a greater difference between corn and proso millet in impact on seedling emergence.

Fall emergence (between August and October) of winter annual grasses in various crop canopies has been explored for the last 7 years. Results show that for every seedling that emerges in proso millet, 1.6, 3.7, and 3.8 seedlings emerge in sorghum, corn, and barley, respectively. These long-term data indicate that producers would enhance seed bank depletion if they planted corn or barley rather than proso millet or sorghum after winter wheat in their infested fields.

Seedling emergence of jointed goatgrass and downy brome have been recorded from designated sites over a 3-yr period. Jointed goatgrass persists longer in the soil than downy brome, therefore a longer time span between winter wheat crops will be required to allow adequate seed bank depletion to occur. The highest seedling emergence per month for both species occurred in October, followed by September, then March.

INTERPRETATION: If jointed goatgrass and downy brome are present in a field, producers should sweep plow once after winter wheat harvest, followed by corn in the rotation. Proso millet or sorghum impose a microclimate that is not conducive for germination and emergence of either jointed goatgrass or downy brome. Therefore, producers should target proso millet or sorghum for fields that are not infested with winter annual grass weeds.

FUTURE PLANS: Data will be collected for the duration of this study and published after statistical analysis.

CULTURAL MANAGEMENT SYSTEMS FOR WINTER ANNUAL GRASS CONTROL IN WINTER WHEAT

R.L. Anderson
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00D

PROBLEM: Herbicides options for within-crop control of downy brome are presently limited and expensive, while no within-crop control measures for jointed goatgrass and volunteer rye presently exist. However, several cultural practices have been shown to limit the growth and interference of downy brome in winter wheat. For example, delaying planting of winter wheat allows more time for downy brome to germinate before wheat planting and be controlled by tillage and/or herbicides. Winter wheat cultivars also differ in their competitiveness with downy brome, with taller varieties tolerating downy brome interference with less yield loss. Other cultural practices reducing brome interference include narrow row spacing, increased seeding rate, and N fertilizer placement.

The majority of research exploring cultural practice effect on downy brome has focused on only 1 or 2 practices. The objective of this research project is to compare production systems composed of various combinations of cultural practices for managing winter annual grasses within winter wheat.

APPROACH: Experimental design is a randomized complete block with four replications. Treatments consists of eight management systems composed of various combinations of 3 cultural practices easily implemented by producers. The cultural practices evaluated include: 1) winter wheat variety (Lamar vs Tam 107), 2) seeding rate (45 vs 72 kg/ha), and 3) N fertilizer placement (N applied in April of fallow vs N applied in April + banding N with the seed at planting). Plot size is 9 by 9 m. Within each plot, a development site is designated where downy brome, jointed goatgrass, and winter rye are established 7-10 days after wheat planting by use of peat pellets. Subplot size is 2 by 3 m.

A conventional system currently used by producers in this region, planting a semi-dwarf cultivar (Tam 107) in mid September at 45 kg/ha, was included for comparison. Nitrogen fertilizer (67 kg/ha) was applied in August with a tillage operation (sweep plowing).

Winter wheat yield were determined from the weed-infested and a weed-free site for each plot at harvest. Yield components of wheat also were determined for both sites. Tillers/m^2 within each designated site were recorded, 20 spikes randomly selected, and seeds/culm and seed weight determined.

Downy brome, jointed goatgrass, and winter rye development was monitored from 6 plants in each system in all replications.

FINDINGS. Weed response. One cultural system, Lamar planted at 72 kg/ha with N applied in April, reduced all species' seed production (also biomass production) compared to the conventional production system. Seed production for volunteer rye was reduced 30%, and jointed goatgrass 40% by this system. Downy brome was infested with smut, therefore, no seed production data was collected for this species. Plant biomass data indicated that cultural systems impacted downy brome growth similar to volunteer rye and jointed goatgrass.

Banding N with winter wheat seed at planting did not favor winter wheat over weeds, but surprisingly, in some systems with Tam 107, banding N increased weed seed production. Apparently, roots of the weeds reached the N band early in their development, increasing their competitiveness with winter wheat.

Winter wheat grain yield response. Lamar yielded less than Tam 107 in all systems. Planting Lamar at 72 kg/ha with N fertilizer applied broadcast in April resulted in winter wheat grain yields being 17% lower than the conventional system. Lamar yields less than Tam 107, but because of it's taller growth habit, it inhibits grass weed growth more.

INTERPRETATION: These results show that cultural practices at planting can reduce volunteer rye and jointed goatgrass seed entry into the seed bank, consequently lessening future infestations of these weeds in winter wheat.

FUTURE PLANS: The results from this study will be used to develop a study exploring management systems for control of jointed goatgrass, downy brome, and volunteer rye. The systems will be longer-term in time, involving rotations, mowing, cultural practices at planting time, and control options within the crop.

WILD BUCKWHEAT ECOLOGY AND INTERFERENCE IN WINTER WHEAT

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CRIS: 5407-12130-003-00-D

PROBLEM: Wild buckwheat is a prevalent weed in the Central Great Plains, and causes significant yield losses in wheat. Herbicide options exist for wild buckwheat, but knowledge about wild buckwheat's ecological characteristics is very limited.

Environmental concerns have stimulated a research focus on a more balanced approach to weed control, incorporating cultural practices with herbicide options into management systems. Developing effective integrated management systems for specific weed species requires knowledge about ecological characteristics such as time of seedling emergence, rate of seedling development, and peak growth periods. Differences in growth patterns can be exploited to favor one species. For example, downy brome roots seldom penetrate deeper than 33 cm, whereas winter wheat roots can penetrate to 200 cm. Applying N fertilizer in April of the fallow season results in N leaching below the rooting zone of downy brome, and consequently less downy brome growth within winter wheat. Ecological knowledge of wild buckwheat may lead to possible control measures based on life cycle vulnerabilities.

The objectives of this study are characterize wild buckwheat's emergence pattern, growth and development as affected by time of emergence, soil water extraction depth, and time of removal effect on winter wheat grain yield loss, plus develop a yield loss equation based on wild buckwheat populations in winter wheat.

APPROACH:

Statistical Design: All studies are a randomized complete block design with 4 replications, unless otherwise stated.

Ecology studies

1. Emergence pattern: 250 seeds of wild buckwheat will be planted 1-2 cm deep in soil in five 1-m^{-2} sites. Seedling emergence will be counted weekly, with seedlings removed after counting. Counts will begin March 1 and continue until wheat harvest. Soil temperature will be recorded with thermocouples and the data logger.

2. Growth and development study: Ten seedlings of wild buckwheat (germinated in peat pellets) will be established in winter wheat starting on April 1 and weekly until May 5.

Development will be monitored weekly, and biomass and seed production will be measured at winter wheat harvest. Plot size is 2 m by 3 m.

3. Rooting depth study: Tam 107 winter wheat and wild buckwheat will be established in the following treatment sequence: Tam 107 alone, wild buckwheat alone, Tam 107 + wild buckwheat, and a control of no plants. Access tubes will be placed in the center of the plot. Neutron probe readings will be taken weekly, starting on April 1. Plot size is 3 m by 3 m.

Interference studies

1. Yield loss equation based on wild buckwheat populations: Wild buckwheat will be broadcast to the soil surface in September before winter wheat planting to achieve the following populations: 5, 10, 25, 50, 100, and 200 plants/m^{-2}. Tam 107 will be planted at 45 kg/ha. Plots will be split, with a control included for each population. Infested and control subplots will be harvested from each plot. Plot size is 3 m by 7 m.

2. Time of removal study: Wild buckwheat will be broadcast to the soil surface in September before winter wheat planting to achieve a population of 200 plants/m^{-2}. Tam 107 will be planted at 45 kg/ha. Buctril will be applied on April 8, and weekly until May 5. Buctril can be applied to winter wheat regardless of growth stage without injuring wheat, yet has high efficacy on wild buckwheat. Two control treatments are included. Buctril efficacy on wild buckwheat will be visually estimated 7 and 14 days after treatment, to account for winter wheat interception of spray. Plots will be harvested at maturity for grain yields. Plot size is 6 m by 7 m.

FINDINGS: Study was established in the fall of 1993.

INTERPRETATION: None at this time.

FUTURE PLANS: This study will be repeated, then published in Weed Science.

WEED MANAGEMENT SYSTEMS FOR SUNFLOWER

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CRIS: 5407-13000-002-00D

PROBLEM: Sunflower has potential to become a major crop in the Central Great Plains. It is classified as a non-compliance crop in the government program, thus, producers can grow sunflower without affecting their wheat base. However, one obstacle to sunflower production is residue level compliance for the government program. The prevalent herbicide used for weed control in sunflower is treflan (trifluralin), which requires incorporation for effective control. This incorporation eliminates surface residue and results in fields failing to meet the 30% cover requirement after planting.

A granular formulation of treflan applied at 1.1 kg ai/ha with limited incorporation has been successful in North Dakota. Application occurs in late fall or early spring, and a sweep plow (1 or 2 operations) is used for incorporation. This technique minimizes residue burial and relies on precipitation to aid in incorporating the granules.

Prowl (pendimethalin) has performed well when surface-applied without incorporation. Applying prowl at 1.5 lb/ac in mid-May controlled weeds for 90 days during chemical fallow, while a 1.0 lb/ac rate controlled weeds in safflower for 63 days. Prowl is currently labeled for surface-applied preemergence use in sunflower.

Tillage intensity affects crop growth in the Central Great Plains. For example, grain yields of corn, proso millet, and safflower were increased by 35, 20, and 10%, respectively, in a no-till system when compared to a tillage system of sweep plowing and disking for weed control and seedbed preparation. Tillage effect on sunflower production, however, has been inconsistent. In eastern North Dakota and Texas, sunflower grain yields were not affected by tillage system, while in central North Dakota, no-till systems increased grain yields only during drought years, not during normal precipitation years.

The objective of this study is to compare management systems composed of combinations of tillage and herbicides for controlling weeds in sunflower.

APPROACH: Six systems were compared, 4 systems within a stubble mulch fallow method and 2 systems within no-till fallow. The stubble mulch fallow consisted of sweep plowing as needed in the fall and spring before sunflower planting. The 4 treatments in stubble mulch fallow were: 1) liquid treflan (1.0 lb/ac) applied in May and incorporated with a disk; 2) granular treflan (1.0 lb/ac) applied in October, followed by a second application of granular treflan (0.5 lb/ac) in May; 3) granular treflan (1.0 lb/ac) applied in May; and 4) granular sonalan (1.0 lb/ac) applied in May. No-till fallow consisted of command + atrazine (0.5 +0.5 lb/ac) applied in late July. The 2 treatments in no-till fallow were 5) granular treflan (1.0 lb/ac) applied in May and 6) liquid prowl

(1.5 lb/ac) applied in May without incorporation. Treflan in treatments 2, 3, and 5 and sonalan in treatment 4 were applied with the Gandy air system and incorporated with the sweep plow and mulch treaders. Nitrogen was applied at 80 lbs/acre for all treatments.

Experimental design was a randomized complete block with 4 replications. Plot size was 9 by 13 m.

Soil water storage and crop water use were measured by gravimetric samples (1-foot increments to a 6-foot depth) taken after wheat harvest, November 1, April 1, before sunflower planting, and after harvest. Using the line transect method, residue levels were measured on the same dates that water samples were collected. Sunflower development and plant height were recorded weekly on 3 designated plants per plot. Sunflower grain yield and 1000-seed weight were recorded at harvest. Visual estimates of % of plot area that is weed-free were made weekly until canopy closure. When level of weed infestation exceeded 15% of the plot area, weed biomass by species were recorded from two 1-m^2 quadrats in each plot. If weed cover did not exceed 15%, species, population, and biomass were recorded at canopy closure. Four m^2 sites were marked in a no-till site and stubble mulch site within appropriate treatments in the study and weekly emergence of weed species recorded during the sunflower growing season (June 10 - Nov. 1).

FINDINGS:

1). Water storage and use. Precipitation storage efficiency for the fallow period was 49% for the stubble mulch method and 63% for the no-till fallow method. Soil water was increased 12 cm with stubble mulch and 16 cm with the no-till system.

2). Winter wheat residue measurements. All systems maintained residue levels above 30% until seedbed preparation in early June. With system 1, where the disk was used to incorporate liquid treflan before planting, residue cover dropped to approximately 20%. The other systems had residue cover > 50% at planting.

3). Sunflower growth and grain yield. Sunflower development was not affected by tillage system. Flowering occurred by August 15 in all systems. Grain yield ranged from 2800 to 2920 kg/ha, with no difference among tillage systems.

4). Weed control. All systems maintained > 85% weed control until flowering. Weed infestations of < 15% did not affect yields, demonstrating that sunflower tolerates low weed infestations. The no-till system with prowl applied preemergence to the weeds was successful in minimizing weed interference with sunflower.

INTERPRETATION: Producers can achieved acceptable weed control and maintain surface residue levels with the use of reduced- and no-till systems for sunflower production. These systems allow the producer to grow sunflower within government compliance regulations.

FUTURE PLANS: Conclusions from this study will be used to guide future research in no-till sunflower production systems.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

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CRIS: 5407-12130-003-00D

PROBLEM: The winter wheat-fallow rotation is the major production system for rain-fed agriculture in the semiarid Great Plains. This system is not favorable for maintaining soil quality, and the lack of commodity diversity makes the producers more dependent on climatic conditions. Because precipitation is erratic, this production system reliance on one crop results in a boom-bust economy.

The Central Great Plains Resource Management Research Unit is exploring alternative cropping rotations, with the goal to increase cropping intensity and consequently, cropping diversity (See research report on alternative crop rotations in this report). The CSU Eastern Colorado Research Center (ECRC) at Akron (Range Station) is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and market for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage). Some crops being explored in the above mentioned rotation study have potential as a livestock protein supplement, such as sunflower. If sunflower can be used as a feed supplement for livestock, this use would increase the market potential for this alternative crop in the Central Great Plains. If livestock was a component of production systems, this also would supply a market for dryland corn, which is increasing in hectarage in this region.

The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of land resources to support livestock production by using crop aftermath and alternative forages while reducing annual cow costs. The economic sustainability of each system will be evaluated.

APPROACH: Three studies are being planned to evaluate integration of a crop rotation system into an Eastern Colorado dryland ranch. The research is being conducted at CSU-ECRC located 19 miles north of Akron.

<u>Study 1</u>: Evaluate the effect of triticale production for forage on economics of annual cow costs. Triticale forage will be grazed by cattle in the spring to compare their overwintering costs versus cattle maintained on standing dormant winter native range and supplemented with protein.

<u>Study 2</u>: Evaluate the effect of feeding sunflowers whole or roasted on gestating cow weight change, calf birth weight, and reproductive performance. Sunflower seed fed whole or roasted will be compared to cottonseed meal for effect on cattle production.

Study 3: Evaluate the potential for grazing crop aftermath. This study will compare weight gain of cattle grazing 1) native range, 2) cornstalks, or 3) sunflower stalks.

FINDINGS: Studies were initiated in late spring and the fall of 1993. Drought conditions limited corn yields to 27 bu/ac and sunflower yields to 600 lb/ac on a sandy loam soil in 1993.

INTERPRETATION: None at this time.

FUTURE PLANS: Research exploring the integration of cropping systems with livestock production has been requested by numerous producers, and this study's long-term objective is to develop integrated production systems for diversified farms.

WEED EMERGENCE PATTERNS AND SEED BANK CORRELATION FOR A BIOECONOMIC HERBICIDE DECISION MODEL

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CRIS: 5407-12130-003-00-D

PROBLEM: A weed-corn bioeconomic simulation model has been developed to aid producers in making herbicide choices. Weed seed numbers in soil is used to make soil-applied herbicide decisions, while within-crop weed seedling densities guide post-emergence herbicide decisions. This model computes gross revenues, herbicide and application costs, and gross margins based on selected management strategies. Field research shows that herbicide use can be dramatically reduced without sacrificing profits.

The North Central Regional Research Committee 202 was formed in 1991 to develop a national bioeconomic model for corn and soybean based on the precursor model developed for irrigated corn. One sub-committee is exploring seed bank dynamics and seedling establishment. Their goal is to characterize the emergence patterns of common weeds infesting corn and soybean, and develop a submodel characterizing their emergence pattern.

Knowledge of the timing and extent of seedling emergence from seed banks can guide producers in 1) altering planting dates to avoid weed problems, 2) timing within-crop tillage or herbicide application to maximize effectiveness, and 3) using the bioeconomic model's postemergence decisions.

Several scientists have attempted to develop relationships between soil seed bank populations and seedling populations during the growing season. Accuracy has been very low, limited to a few species, and only within irrigated systems where erratic patterns of precipitation are minimized. The value of seed bank knowledge within the bioeconomic model is minor compared to within-crop seedling populations, but it is used by the model to suggest preemergence treatments. The model needs a measure of variability of seed bank-seedling population relationship within rain-fed production systems in order to assess predictive accuracy for users.

The objectives of this study are: 1) characterize the emergence patterns of weeds during the corn growing season (April 1 to September 31), and 2) determine the correlation between seed bank samples and the following seedling emergence for all species recorded.

APPROACH: Plots were established in a no-till system. Plot size was 6 m by 6 m, with 4 replications. Seed bank samples were collected at initiation of study (April 1). Twenty soil cores were collected with a hand probe (3 cm in diameter) in a W pattern across each of the 4 plots. Each core was stored and analyzed separately. Extraction procedure followed the

techniques developed by Schweizer and D'Amato. Seeds extracted from the soil samples were identified and counted. Seeds were counted as viable if firm when pressured by a forceps. Both live and dead seed were recorded. Live seed was incubated at 25/15 C (day/night temperatures) for 2 weeks and number of germinated seeds was recorded.

Ten permanent quadrats were established in each of the 4 plots. Quadrat size was 0.25 m^{-2}. Seedlings were identified, counted by species, and removed from each quadrat on a weekly basis throughout the growing season.

Three microclimatic measurements were recorded on a daily basis: soil temperature (5 cm depth), air temperature, and rainfall.

FINDINGS: Ten weed species were observed at the Akron site. Pigweed species (redroot, smooth, and prostrate), proso millet, kochia, Russian thistle, and Mare's tail were the most common seedlings recorded. The emergence pattern for the community showed two peaks, a minor peak in early May when kochia, Russian thistle, and Mare's tail emerged, and a major peak during early June, when the pigweed species emerged. Of the total number of seedlings, 95% were pigweeds.

The seed bank population data was sent to Forcella in Minnesota for a regional analyses of seed bank correlation and seedling emergence. The pigweed seed bank and emergence data was compared to Forcella's emergence model for pigweeds, and the results indicated that his model was accurate in predicting when the pigweeds would emerge at this location.

The regional results for correlating seed bank populations and seedling emergence was presented at the North Central Weed Science Society meetings in December.

INTERPRETATION: Producers are seeking decision-aid models to reduce herbicide input costs and release into the environment. The bioeconomic model recommends herbicides only if needed, based on seed bank and within-crop seedling emergence knowledge. This study is building a data base for sub-models in the overall model being developed by the NC-202 committee, which will be used for corn and soybean production systems throughout the United States.

FUTURE PLANS: Incumbent (RA) is working with Lori Wiles in developing a weed emergence model based on emergence data collected at Akron for the last 7 years. A long-term goal is to work with Ed Schweizer and Lori Wiles to parametize their bioeconomic model for dryland corn in semiarid regions.

METHOD DEVELOPMENT FOR EVALUATION OF C AND P POOLS TO ASSESS SOIL QUALITY

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CRIS: 5407-12130-003-00D

PROBLEM: In the semiarid areas of the Great Plains, continued wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of decomposition. This loss is even greater because of the high erosion hazard associated with plowing the plains areas where winter winds are pronounced during the fallow periods. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical and chemical properties such as rooting depth and soil aggregation. Total pools of organic C and P in croplands are sometimes inadequate as predictors of trends in soil deterioration because they lack sensitivity over the short term (1 to 3 years). A need exists to develop methodology to assess soil quality changes and direction of change. The specific objective, therefore, was to develop easy sensitive organic C and P methods to assess soil quality, and consequently, soil productivity in croplands. Methodology is based on correlations with measures of soil microbial activity such as the phosphatase activity, and on water- and base-soluble organic C and P, and carbohydrate-C (binding for aggregates) which, hopefully, may integrate losses due to erosion, decomposition, and gains due to organic matter inputs from previous cropping.

APPROACH: Experiments were continued on soils from selected alternate cropping plots and adjacent native sod sites. Tests for extractability of soluble organic C and P from water (high soil/solution ratios), salts, and dilute base and acids continued. These soils were selected so true comparisons could be made between no-till and reduced-till treatments. In other words, only the same cropping sequences were compared. As before, these pools were regressed against total pools, established methods for labile pools, and selected measures of soil microbial activity such as the phosphatase activity for biological correspondence. Where possible organic C and P were measured in the extracts, and color intensity of basic extracts was determined as a measure of soluble C. Procedures to evaluate structural or aggregate stability were continued in which the flocculation-dispersion behavior of the clay was measured by optical transmittance (turbidity). The aggregated clays are more flocculated, and therefore show a greater light transmittance when allowed to settle overnight. A method for soil reduced sugars by anthrone (anthrone-reactive carbon, ARC) is also being evaluated.

FINDINGS: Tests with these extractants for a measure of soluble C (water, 0.05 M $NaHCO_3$, 0.05M K_2SO_4, 0.05 M NaOH, and 0.05 M NaOH after treatment with 1 M acid) continued. The intent was to come as close as possible to the pool in the solution phase while at the same time having a relatively easy and reproducible way of extracting sufficient measurable organic C. As before, total C was determined from colorimetric procedures based on dichromate

reduction and on extract color absorptivity (NaOH and NaOH plus EDTA) at 550 nm. Initial results from the turbidity study indicated clear differences between cultivated and native sod plots, the latter showing lower turbidity. The ARC procedure (sugars extracted in 0.05 M K_2SO_4) showed good reproducibility for standards and spiked sugars. Data show that sod and grass treatments have low levels of soluble organic carbon (probably from grass root hydrolysis). As shown before, conventional-till plots showed higher soluble carbon than other tillage systems. There was also a trend for higher soluble carbon in plots previously in corn.

INTERPRETATION: Sampling was conducted on differently treated sites to obtain a better representation of treatment effects. The method of choice at this time is extraction with 0.05M $NaHCO_3$ and 0.05M K_2SO_4 where there is no turbidity interference as occur with water alone. Extracts can then be evaluated colorimetrically for reduced sugars (anthrone) or total organic carbon (dichromate). Data for the residual organic C showed higher values for longer rotations sequences especially where millet was last grown (still needs much more evaluation though), and lower values under conventional till. Turbidity studies still require evaluation because of lack of response among selected cropped sites where significant total carbon differences were obtained. Trends among cultivated sites still need to be developed since differences may be small and variable. The ARC procedure may hold some promise for ease and reproducibility for available organic carbon.

FUTURE PLANS: Future plans remain essentially the same as last year. Methodology development will continue with more tillage and rotation combinations, and with soils that provide distinct differences in organic matter such as soils in a catenary sequence, and soils in various phases of grass reestablishment (Conservation Reserve Program). Soils from the CRP are now available. Emphasis will be placed on correlations of water-soluble and residual organic C with the various cropping sequences. Soluble sugars-C and turbidity studies will also continue as an indicator in evaluating aggregate stability.

P, C, AND MICRONUTRIENT DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

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CRIS: 5407-12130-003-00D

PROBLEM: The dominant dryland cropping system in the Central Plains is the two-year cycle of conventional-till (CT) winter wheat and fallow (WW-F). Numerous studies in the Great Plains have shown that this system may not be the best for efficient utilization of water and nutrients. Additionally, if one could introduce another crop or two into the rotation system without a deterioration in soil productivity (No-till (NT) systems) or weed infestation (Reduced-till (RT) systems), then farm income can be obtained 8 or 9 times in 12 years as opposed to 6 in a conventional wheat-fallow system. The challenge then becomes one of choosing the right set or sets of rotations, that are economically desirable and simultaneously maintain or improve soil productivity. This is the objective of the station team research. My specific objectives are: to monitor changes in soluble and total organic matter, P, and Zn under selected alternate cropping (one to four-year rotations) and tillage (NT, RT) systems as compared to the standard clean-till wheat-fallow rotation. Additional objectives are to monitor changes in pH, bulk density, texture, aggregation, and infiltration.

APPROACH: The study is located at Akron CO on a Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Halvorson, Hinkle, Nielsen, Anderson, Bowman, and Vigil for treatments). Extensive sampling was conducted on all 180 sites for soluble and total organic carbon, color intensity of base extraction, pH, bulk density, phosphatase activity, bicarbonate-extractable P, total organic P, and total P. Soil samples were collected at 0-15 cm (6 inches), and at 0-5 cm (2 inches) for plow layer evaluations and for stratification evaluations especially under the no-till conditions.

FINDINGS: Generally, data on organic carbon in the surface two inches showed a definite trend towards increasing carbon content with less tillage and as cropping intensity increased (Table 1). Wheat-fallow systems contained the least organic matter content while continuous cropping contained the most. Average loss of organic carbon in plots when compared to the native sod was about 50%. Data at the 2-6 inch depth did not vary much (about 0.6% C). The data showed that conventional cropping had the highest soluble organic carbon content. There was a significant drop in pH (0.01M $CaCl_2$) because of cultivation (pH = 5.7) when compared to the native sod (pH = 6.3).

INTERPRETATION: New soil samples showed essentially the same trends as previous soil samples. Conventional-till treatments had the highest soluble carbon content probably because of greater mixing and exposure to oxygen, and consequently, greater degradation of larger

compounds. This also causes the greater loss in total organic carbon because of decomposition to CO_2. Cropping intensity increases organic matter because of greater residue production. The drop in pH was to some extent due to the use of ammoniacal fertilizers over time. While no-till also causes a drop in pH (organic acid production in the surface soil), pH for reduced-till was about the same. As more data are collected, and more compositing of cropped and fallow , conventional and no-till are done, changes in labile forms of OC and P will become more evident. Significant results from study may require a number of years since complete cycles range from one to four years, and 12 years are required for adequate standardization.

FUTURE PLANS: Plans are to sample continuously 30 of the 60 treatments for soil organic matter and nutrient changes. On selected site samples, we hope to evaluate aggregation, texture, and water infiltration, and to continue to determine labile pool changes of C, N, and P. At this time, there is no intention to study micronutrients unless field plant symptoms show specific needs.

Table 1. Changes in organic C, N, P and pH under different tillage and cropping systems. (0-2 inches).

Cropping	Soil Parameter			
System	Organic C	N	P	pH
		%		
Native Sod	1.57	0.152	0.018	6.3
Conventional-till	0.73	0.077	0.010	5.7
Reduced-Till	0.86	0.083	0.010	5.6
No-till	0.86	0.089	0.011	5.8
WW-F	0.79	0.08	0.010	5.8
Continuous Cropping	0.88	0.096	0.011	5.7

P and ZN DYNAMICS IN NO-TILL WHEAT AND CORN

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CRIS: 5407-12130-003-00D

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (40 bushel dryland wheat requiring about 83 kg N and about 12 kg P, with 75 bushel dryland corn requiring about 100 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies.
The objectives of the research, therefore, are to evaluate the need for P and micronutrients in no-till wheat and corn, to measure changes in forms and availabilities of P with time, and to predict yield responses for these nutrients.

APPROACH: Two sites have been selected, one at Peetz, CO for evaluation of no-till wheat (See report of Halvorson and Havlin for plot design and treatments), and one at Akron, CO on a Platner loam soil also for wheat (previously in corn). Only selected samples from the broadcast sites with and without N (48 sites) are been studied at Peetz. Treatments for the wheat study are: four replications with randomized NP factorial (4 N x 5 P for a total of 20 treatments per replication). Nitrogen applications were: 0, 40, 80, and 120 lb/Ac of N as NH_4NO_3, and 0, 30, 60, 90, and 120 lb/Ac of P as triple superphosphate (0-46-0). For the wheat study soil samples were taken from both east and west plots in May, 1993, and from previous collections by Halvorson and Havlin. Whole wheat plants were harvested once only . Total and available P pools were determined on the soils, and total N, P, and Zn on the plants. For the Akron site soil samples were taken down to 90 cm on all 60 sites, and to 180 cm on the 0 and 120 P sites in October. Whole plant samples were taken on 4-28-93.

FINDINGS: Consistent with last year's results, data on P uptake in wheat (both sites) showed that increasing N and P treatments resulted in corresponding increases in tissue-N content and tissue-P content (Table 1). Dry matter yields and grain yields, though, were generally a function of N levels. This was expected at the Akron site since the zero P level sites were high (> 15 ugP/g).

INTERPRETATION: In both wheat studies, soil levels of available P were high, average for 0 P in the wheat at Peetz being about 15, and that at Akron about 25. There may have been a problem with the application of the P fertilizer at the Akron site since this is the third year in a row that values have been above 20 where previous values before study were 10. The data

in table 1 show significant increases because of N fertilization. Grain yields increased about 70% over the zero N level. Both N and P fertilization resulted in increased N and P in the tissue. Nitrogen by P interaction was minimal since control plots were already high in P.

FUTURE PLANS: These studies will be discontinued because of serious confounding at both sites. Over the past three years the Peetz site has eroded extensively, and much of this eroded soil has washed up on other treatment plots. Data on P dynamics on non-affected plots will be evaluated for final data treatment. The Akron site does not have a low (control) P site, and this has caused some concern over data interpretation (relative yield as a function of P levels). Since treatments at both sites represent N X P factorial, and are within the same climatic regimes, an attempt will be made to combine data for a manuscript.

Table 1. Effects on N and P levels on relative dry matter (DM) yield, N and P concentrations in dry matter, and grain yields. Akron Site.

Fertilizer levels	DM yield/foot	Wheat (4-28-93)			Yield**
N lb/Acre	grams	% N	N Uptake*	% P	Bu/Acre
0	19.1	1.87	363	0.35	37.5
40	25.0	2.95	738	0.39	59.2
80	28.0	2.97	832	0.35	65.0
120	31.3	3.84	1202	0.32	63.2
P lb/Acre		% P	P Uptake	% N	
0	23.4	0.30	70	2.75	56.2
30	26.8	0.33	88	2.90	56.0
60	26.2	0.36	94	2.90	56.1
90	25.9	0.40	104	2.99	54.8
120	26.4	0.42	111	2.99	58.0

* Nutrient uptake/foot of row.
** Yields at different N levels represent average for all P treatments, and yields at different P levels represent average for all N treatments.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

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Central Plains Resource Management Research Unit

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PROBLEM: Present Center projects relevant to CRP address soil and vegetation changes on small station plots (See Halvorson and see Schuman). Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Nine farms in Washington County on the Conservation Reserve Program were selected from data obtained through SCS. Three went into the program in 1986, three in 1988, and three in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP.

Soil parameters of interest include: organic carbon, TKN, available P, Cation Exchange Capacity, pH, texture, bulk density, water infiltration, and aggregation. Soils will be sampled at 0-15 and 15-30 cm with a minimum of three field replications with five composites. Forage quality among the three CRP sites will also be evaluated.

FINDINGS: All nine farmer sites (27 different sites because of native sod and winter wheat-fallow adjacent sites) were sampled in the spring of 1993. All data for soil organic carbon, N, and P have been analyzed. Although data for the native sods (0-2 inches) averaged over 1.5% organic carbon (2.5% organic matter), data ranged from 0.79 to 2.12%. The wheat-fallow averaged 0.88%, and the CRP site, 0.94%. For total N, the values for sod, WW-F, and CRP were 0.135, 0.076, and 0.077%, respectively. These trends were also reflected in the 2-6 inch depth. Organic P generally reflected the same trends as organic carbon.

INTERPRETATION: Of the nine sites, four had lost over 50% of the soil organic matter because of the clean-till winter wheat-fallow system. Losses ranged from slightly over 20% to over 75% in one site. Average loss was 44%. Over all nine sites, carbon results for three CRP-treated sites were the same as those for the WW-F sites indicating negligible improvement in soil organic matter. For two CRP sites carbon concentrations were lower than the adjacent WW-F, and for four sites higher than their corresponding WW-F values. When evaluated on the basis of year put into the program (86, 88, 90), only the 88 site showed significant increase in organic matter in the CRP site compared to the existing adjacent winter wheat - fallow.

FUTURE PLANS: Sample collection will continue at these sites to help evaluate organic matter gains and losses. An attempt will be made to determine the amount of stable (resistant) organic carbon in matching sod, WW-F and CRP sites to determine the relative fragile (or resistant) nature of the CRP site. It is assumed that the sites with the greater proportion of humic material synthesis will be less subject to wind and water erosion.

EFFECT OF NITROGEN FERTILIZATION ON WATER-USE EFFICIENCY BY CROPS GROWN IN AN ANNUAL CROPPING SYSTEM

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PROBLEM: Limited water for dryland crop production in the Central Great Plains area requires that precipitation be used efficiently. Limited information is available in the Central Great Plains describing the effects of nitrogen (N) fertilization on grain/forage yield and quality, and on water-use efficiency of crops (corn, barley, winter wheat, oats) produced in a no-till annual crop rotation. Basic data on soil fertility and yield-plant water relationships for these crops is needed in order to make crop management decisions that will most efficiently use limited water supplies and fertilizer inputs.

APPROACH: A dryland study site was established on a silt loam soil located on the Central Great Plains Research Station in September 1983. The N fertilizer treatments were initially established in the fall of 1983. The phosphorus (P) soil test level was 26 mg/kg (ppm). Fertilizer N rates are 0, 22, 45, 67, 90, and 134 kg N/ha with 4 replications in a randomized complete block design. The cropping history and grain/forage yield of these treatments are given in Table 1. Because spring barley has not yielded consistently and was severely damaged by heat stress in 1990, an oat-pea forage was selected as the spring crop following corn for 1992. The plots were planted to corn (Pioneer 3732) on April 29, 1993 with a JD Maximerge drill (30" row

Table 1. Cropping history and grain/forage yields.

		N Rate (kg/ha)					
Year	Crop	0	22	45	67	90	134
		Yield, kg/ha					
1984	Barley (grain)	2573	3778	3729	4153	4066	3516
1985	Corn (grain)	4143	4686	5991	6326	6085	6662
1986	Barley (grain)	448	1177	2066	2346	2854	3152
1987	Corn (hailed out on Aug. 4, winter wheat planted Sept. 14)						
1988	W.Wheat(grain)	2623	3022	3235	3637	3406	3182
1989	Corn (grain)	2561	3264	3333	3771	3330	4114
1990	Barley (grain)	135	442	974	1105	957	884
1991	Corn (grain)	4257	4849	5849	6416	6112	5999
1992	Oat-Pea(forage)	732	1813	3071	3627	4377	4965
1993	Corn (grain)	2536	2871	3943	5212	4913	5288
Average	(10 years)	2001	2590	3219	3660	3610	3776

spacing) and harvested for silage on August 27, 1993 and for grain on October 26, 1993. Ammonium nitrate was broadcast applied on April 26, 1993, prior to seeding at rates of 0, 22, 45, 67, 90, and 134 kg N/ha. Soil water, nitrate-N (NO_3-N), and growing season precipitation were monitored. Grain and silage yield and quality were determined.

FINDINGS: Corn silage yields (70% moisture) for the 0, 22, 45, 67, 90, and 134 kg N/ha treatments were 16.6, 19.7, 28.7, 31.6, 31.1, and 32.0 t/ha with grain yields of 2536, 2871, 3943, 5212, 4913, and 5288 kg/ha, respectively, for 1993. Precipitation from April 22 through October was 34.0 cm with a very dry August and September which limited grain yields. An early September frost also reduced final grain yields. Soil water use from the 0- to 180-cm soil profile was estimated to be 4.9 cm. Growing season precipitation amounted to 34.0 cm for a total estimated ET of 38.9 cm (15.3 inches) for 1993. Thus, water-use efficiency (WUE) by dryland corn increased as N fertility level increased up to an application rate of 134 kg N/ha. WUE levels were 65.2, 73.8, 101.4, 134.0, 126.3, and 135.9 kg grain/ha/cm water for the respective N treatments.

INTERPRETATION: Although precipitation was erratic during the 1993 growing season, an excellent corn crop was harvested in 1993, at this annually cropped site. This was the 10th consecutive crop produced on these plots since 1984. Thus, for an annual dryland cropping situation, the average grain yield (Table 1) with an adequate level of N are acceptable and economical, even with one year (1987) of total crop failure and one year (1990) of very low grain yield. Residual soil NO_3-N data indicate that efficient use of the fertilizer N has been made up to a rate of 67 kg N/ha. At the highest N rate, N fertilizer has been used less efficiently with a significant buildup of residual NO_3-N in the soil profile. These data demonstrate the potential to economically crop more frequently than every two years, as is done in a winter wheat-fallow system, when adequate levels of soil water and N are available.

FUTURE PLANS: The project will possibly be continued in 1994 with each N treatment being applied at its normal rate. Corn (Pioneer 3732) will possibly be planted no-till on the plot area in late-April 1994. Soil samples to assess the effects of N fertility rate on soil organic matter will be collected and analyzed. Plans are to make a detailed economic evaluation of the yield data.

CROP ROTATION AND NITROGEN FERTILIZATION FOR EFFICIENT WATER USE

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PROBLEM: In the western portion of the Central Great Plains, the winter wheat- fallow rotation is the dominant cropping system. Diversification in crop production has been limited in this area, providing producers with few economic alternatives in years when wheat is in surplus supply or soil water levels are high. The winter wheat-fallow (WW-F) system is not the most efficient cropping system for utilizing precipitation. Implementation of reduced tillage and no-till cropping systems has resulted in more efficient soil storage of precipitation. This additional water savings increases the opportunities for successfully growing spring-planted crops such as proso millet, sorghum, and corn in rotation with winter wheat. However, data on the productivity of a winter wheat-corn(or sorghum)-fallow (WW-C-F or WW-S-F) rotation is limited for the western portion of the Central Great Plains. Nitrogen management information for optimum water utilization and crop yields in these cropping systems is lacking. The objectives of this study are to measure the long-term grain yields of each respective crop in WW-C-F and WW-S-F rotations and determine the effects of N fertilization on grain yields and water-use efficiency by each crop, residual soil NO_3-N levels, and economic returns.

APPROACH: The N treatments (0, 28, 56, 84, and 112 kg N/ha applied each crop year) are randomized in a complete block design with 4 replications on a Platner loam soil near Akron, CO. Each main N plot is split following winter wheat with half the plot planted to corn and half to sorghum. Three sets of no-till plots are used to allow each crop of the rotation to be present every year. Soil water and NO_3-N are monitored to assess use by each crop. Nitrogen was broadcast to the wheat plots September 21, 1992. Wheat (Tam 107) was planted September 21, 1992 at a rate of 2.2 million seeds/ha or 900,000 seeds/acre with a Haybuster 1000 disk-type drill (7" row spacing). Corn (Pioneer 3732) was planted April 29, 1993 (36,803 seeds/ha or 14,900 seeds/a) and sorghum (Pioneer 8790) was planted May 19, 1993 (170,430 seeds/ha or 69,000 seeds/a) on the 1992 wheat plots. Ammonium nitrate was broadcast on the corn and sorghum plots on April 27, 1993. Winter wheat was harvested July 6, corn October 27, and sorghum October 27, 1993.

FINDINGS: Winter wheat grain yields were significantly increased by N fertilization in 1993. Grain yields averaged 2199, 3672, 4294, 4105, and 4202 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Extremely dry soil conditions at seeding resulted in very poor emergence of the 1993 winter wheat crop, with a major portion of the seeds germinating over winter. Although precipitation from March to June was below normal, cool summer

temperatures helped the wheat crop survive the drought conditions, resulting in excellent yields on 14.4 cm of growing season precipitation. Grain yields increased with increasing N rate up to 56 kg N/ha and then decreased at higher N rates.

Corn grain yields were significantly increased by N application in 1993, with an average grain yield of 1594, 2931, 4012, 3214, and 3884 kg/ha at 15.5% grain moisture for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Grain yields in 1993 were less than in 1992 due to a cool summer, and the below normal precipitation in August and September. An early September frost contributed to low yields in 1993. Yields were highest at the 56 kg/ha N rate. Silage yields (70% moisture) on August 25, 1993 were 14.1, 21.5, 24.2, 24.9, and 25.3 t/ha, respectively. Soil water use averaged 8.45 cm from the 0-180 cm profile with growing season precipitation amounting to 31.1 cm for a total estimated ET of 34.2 cm.

Sorghum grain yields were significantly increased in 1993 by increasing rates of N fertilization. Grain yields on October 27, 1993 averaged 1966, 2366, 3189, 3204, and 2836 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Average soil water use by the sorghum was estimated to be 4.6 cm from the 0-180 cm soil depth. Growing season precipitation was 34.2 cm. Estimated ET for the sorghum crop was 38.8 cm.

INTERPRETATION: Crop yields were averaged with previous years, resulting in average winter wheat yields (9 yr) of 2265, 3135, 3498, <u>3589</u>, and 3542 kg/ha; corn yields (8 yr) of 1802, 2808, 3349, 3292, and <u>3520</u> kg/ha; and sorghum yields (8 yr) of 1573, 2306, <u>2625</u>, 2615, and 2483 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments. Average corn and sorghum grain yields include the 1987 yields severely reduced by hail on August 4th (>60% loss). The winter wheat, corn, and sorghum yields at this site on this shallow soil (<120 cm to gravel) indicate the potential for more intensive crop rotations for the dryland areas of the Central Great Plains. Fertilization with N will be essential to maintain economic yields. Water use efficiency by dryland crops (winter wheat, corn, and sorghum) can be significantly increased by the application of N fertilizer. Application of 84 kg N/ha to each crop has resulted in optimum wheat yields, while 56 kg N/ha was needed for sorghum and 112 kg N/ha for corn when averaged over years.

FUTURE PLANS: Plans are to soil sample the plots to assess changes in soil chemical and physical properties. The cooperative N^{15} work with Drs. Follett and Porter will continue in 1994 with the plots seeded to winter wheat. Data summarization and completion of a journal publication will continue, along with initiation of an economic analysis. The 1994 winter wheat crop was severely damaged by an over application of bladex during late summer fallow period. The 1994 wheat plots will be seeded to a spring crop, possibly oats or corn.

MANAGEMENT OF PHOSPHORUS FERTILIZER FOR DRYLAND WINTER WHEAT IN REDUCED TILLAGE SYSTEMS

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PROBLEM: Information on management of phosphorus (P) fertilizer in no-till and reduced tillage systems for winter wheat production in the Central Great Plains is limited. Banding of low rates of P near the seed on soils low in available P has been shown to be more effective than broadcast applications of P at the same rate during the first year of application. As the soil test P level increases from low to high, the yield difference between banding and broadcast applications is expected to decrease. On a long-term basis, a broadcast application of P may be equally as effective as a band application at equal rates for wheat production. Application of a one-time, high rate of P fertilizer may be one way to satisfy the P needs of crops grown with reduced tillage and no till systems for several years. This study evaluates this suggestion along with comparing the effects of P placement method on the long-term effectiveness of residual P fertilizer within reduced tillage systems. Objectives of this study are to determine: 1) the most efficient P fertilizer placement method for winter wheat production in reduced tillage systems; 2) the level of P fertilizer needed for optimum winter wheat yields with and without N fertilization; 3) residual P fertilizer effects on winter wheat grain yields in reduced tillage systems; and 4) the effects of N and P fertilization on water-use efficiency by dryland winter wheat.

APPROACH: A split-split plot, randomized block design was used with P placement method as main plots, P fertilizer rate as subplots, and N fertilizer rate as sub-subplots with four replications. The research is located about 6.2 km west of Peetz, Colorado. Specific treatments are as follows:

1) Phosphorus Fertilizer Placement Methods
    a) Broadcast with no incorporation (BCNI)
    b) Broadcast with a shallow disk incorporation (BCI) (15 cm depth)
    c) Deep Band at about a 10 cm soil depth (DB)
    d) Band directly with seed (SP) at 25% of established P rates for 4 crop years
2) Phosphorus Fertilizer Rates Applied in September 1986: 0, 34, 67, 101, and 134 kg P/ha.
3) Nitrogen Fertilizer Rates: 0 and 56 kg N/ha

Grain yield, N and P uptake by grain, soil P, soil NO_3-N, and soil water were measured.

FINDINGS: Winter wheat yields at the Peetz site were limited by drought from planting through late May, with some hail damage after heading. Therefore, treatment differences were small and erratic for 1993 because of drought and hail. During the 1993 growing season, 13.9 cm of growing season precipitation were received from April 1st until soil sampling after harvest (August 3rd), with most of the precipitation received in June. Soil water measurements indicated soil water-use of 13.3 cm from the 0 to 180 cm soil depth at harvest. This resulted in an estimated total water use by the wheat crop in 1993 of about 27.7 cm.

Grain yields were significantly (0.05 probability level) increased by increasing levels of residual P or P fertilization. Grain yields were increased by N fertilization in 1993 by 276 kg/ha. Lack of a larger response to P and N fertilization was due primarily to drought during a major portion of the growing period. Grain yields for the fertilizer P treatments were 1801, 1895, 2164, 2110, and 2171 kg/ha for the 0, 34, 67, 101, and 134 kg P/ha treatments, respectively, when averaged over N rates. Thus, a 363 kg/ha increase in yield was observed with the 67 kg P/ha treatment over that of the check. This concluded the last application of new fertilizer P with the seed (SP) to give equal rates to the BCI, BCNI, and DB P placement treatments. P placement had no significant effect on grain yields in 1993. Grain test weight increased significantly as P level increased up to 67 kg P/ha. Nitrogen application decreased grain test weight.

Phosphorus fertilization resulted in a significant increase in the number of heads per unit area at harvest. Head counts for the residual 0, 34, 67, 101, and 134 kg P/ha treatments were 4.20, 4.10, 4.57, 4.52 and 4.59 million heads/ha, respectively. Nitrogen fertilization significantly increased the number of heads per ha. Total dry matter biomass at heading increased as residual P level increased and with N fertilization. Straw yields at harvest were not increased significantly with increasing P level.

INTERPRETATION: The response of winter wheat to residual P treatments was limited by drought conditions from planting through May in 1993. Winter wheat did respond significantly to residual P that had been applied in September 1986. The positive effect of residual fertilizer P on winter wheat yields during the first four crop years was demonstrated. The study will continue for one more year to further evaluate the long-term residual P effects on grain yield and economic returns.

FUTURE PLANS: The study will be continued in 1994 as planned, but this will be the last field season. Plans are to continue summarization of the data and preparation of manuscripts for journal publication.

NITROGEN FERTILITY NEEDS OF CROPS GROWN WITHIN A REDUCED TILLAGE, FLEXIBLE CROPPING SYSTEM

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PROBLEM: Nitrogen fertilizer management information for crops grown in flexible dryland cropping systems in the western Central Great Plains is limited. More intensive cropping systems generally require more fertilizer N than a crop-fallow system to obtain optimum grain yields. Use of a flexible cropping system, where soil water at planting is evaluated, will reduce the potential for an uneconomical return and make better use of limited water supplies in rainfed cropping systems. In 1993, a winter wheat-sunflower-fallow rotation was initiated on this plot area because of the importance of this rotation as a result of the sunflower processing plant built in Goodland, KS. The study objectives are to: 1) determine the N needs of a dryland wheat-sunflower-fallow rotation using reduced tillage; 2) determine the effects of N fertilizer rate on water-use-efficiency by each crop; and 3) determine the economics of a wheat-sunflower-fallow rotation for the dryland area of the Central Great Plains.

APPROACH: Prior to 1990, the study objective was to evaluate the effects N placement method (broadcast vs band) and N rate on dryland crop yields within an annual cropping system using reduced-tillage methods where winter wheat and spring barley were grown rotation. A randomized, complete block design with factorial combinations of five N fertilizer rates (0, 34, 67, 101, and 134 kg N/ha) and two N placement methods (band and broadcast) with 4 replications were used. In 1990, the crop rotation was altered to a flexible cropping system with sunflower being grown in 1990 and proso millet in 1991 with no additional N applied to the previous N treatments in 1991. Because soil water levels were very low, the plot area was fallowed in 1992 and seeded to winter wheat (Tam 107) in September 1992 with no additional N applied. A winter wheat-sunflower-fallow rotation will be followed starting in 1993. Triplicate sets of plots will be established to have each phase of the rotation present every year.

Sunflower were planted on fallow on an adjacent crop-fallow area maintained for comparison with the annual crop yields. The study is located on a silt loam soil at the Central Great Plains Research Station. A randomized, complete block design with five N fertilizer rates (0, 34, 67, 101, and 134 kg N/ha) with 4 replications was used. No N was applied in 1993. A tillage operation was performed to incorporate the treflan that was applied on May 17th. Sunflower (Triumph 565, oil) was planted on the fallowed plots on May 26, 1993 with a JD maximege drill at a seeding rate of 41,000 seeds/ha. The plots were harvested on October 14, 1993. Grain yield, soil water, and residual soil NO_3-N were measured.

FINDINGS: Sunflower yields on the fallowed plots were 1337, 1525, 1548, 1287, and 1703 kg/ha at 10% moisture for the 0, 34, 67, 101, and 134 kg N/ha treatments, respectively.

Residual soil NO_3-N in the 0-180 cm profile on May 7, 1993 was 152, 207, 213, 254, and 309 kg N/ha for the respective N treatments. Plot variability seemed high in 1993 for unknown reasons. Growing season precipitation amounted to 34.9 cm. Soil water use amounted to 6.9 cm from the 180 cm profile, for an estimated total ET of 41.8 cm. Average water use efficiency (WUE) was 35.4 kg/ha/cm in 1993. Because the study will not be continued in 1994, the 1993 winter wheat data will not be reported.

INTERPRETATION: The 1993 sunflower yields produced on this previously fallowed plot area were acceptable, but lower than expected. Sunflower responded to residual soil N level with highest yield at the highest residual N level in 1993.

FUTURE PLANS: The study will be terminated in 1994. Data collected to date will be summarized and examined for possible economic evaluation and publication.

EFFECT OF TILLAGE SYSTEM AND CROP ROTATION ON WINTER WHEAT YIELDS

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PROBLEM: The winter wheat-fallow (WW-F) rotation is the accepted conventional crop management practice for most of the western portion of the Central Great Plains. Weeds are generally controlled during the fallow period before winter wheat planting with 4 to 6 tillage operations. Weed control with herbicides rather than mechanical tillage has made possible the adoption of reduced and no-till systems for winter wheat production. The reduced-till systems improve soil water storage efficiency during the fallow period, and often result in increased wheat yields. However, costs of herbicides for weed control during the fallow period can result in lower economic returns than when mechanical tillage is used. Wheat yields in a winter wheat-corn-fallow (WW-C-F) rotation may be higher than wheat yields in a WW-F rotation, thus making reduced and no-till systems more economical. This study compares the effects of tillage system in a WW-F rotation with wheat yields produced in a no-till WW-C-F rotation. Specific objectives are to determine: 1) effects of tillage system and crop rotation on soil chemical, physical, and biological factors and productivity; 2) economics of various tillage systems for WW-F; and 3) differences in wheat yields obtained from a WW-F rotation and those produced with a WW-C-F rotation.

APPROACH: This dryland study is located on a Weld silt loam at the Central Great Plains Research Station, Akron, CO. The modifications to the existing two sets of identical plots were made on April 15, 1989. Ammonium nitrate fertilizer, 56 kg N/ha, was applied on September 18, 1992 just prior to planting winter wheat (Tam 107) on September 18, 1992 with a UFT disk drill (8 inch row spacing). Winter wheat was seeded at a rate of 2,124,200 seeds/ha. Corn (Pioneer 3732) was planted on the appropriate treatments on April 29, 1993 at a rate of 36,800 seeds/ha with a JD Maxmerge no-till planter. Corn was seeded on plots that had been in wheat in 1992. Ammonium nitrate, 84 kg N/ha, was applied on April 28, just before planting. Specific treatments are as follows:

1) No till (NT) - Contact and residual herbicides for weed control
2) Bare Fallow (BF) - Sweep tillage in fall, plow in spring then sweep tillage
3) Stubble Mulch Fallow (SM)- Sweep, rod weeder (no plow or disk)
4) Reduced Tillage (RT)- Residual Herbicide after harvest, then spring till
5) Winter wheat-Corn-Fallow (WW-C-F) using a no-till system
6) Corn-Fallow-Winter Wheat (C-F-WW) using a no-till system
7) Fallow-Winter Wheat-Corn (F-WW-C) using a no-till system
8) Continuous Corn (CC) using a no-till system

Treatments 1-4 will be maintained in a WW-F rotation, with the fallow treatments described

above. Primary data to be collected from the plots include: soil water - preplant and after harvest (rooting depth), soil NO_3-N in 0-180 cm, grain and straw yield, crop residue - preplant, grain test weight, number of tillage and herbicide operations performed and costs.

FINDINGS: The 1993 winter wheat grain yield data for the NT, RT, SM, BF, and WW-C-F plots were 3934, 3841, 4037, 4071, and 3960 kg/ha, respectively. Soil water use from the 0-180 cm profile averaged 23.7 cm. Growing season precipitation (April 1 to harvest) was 14.5 cm for a total estimated ET of 38.2 cm. Average water use efficiencies were 103, 101, 106, 107, and 104 kg grain/ha/cm for the NT, RT, SM, BF, and WW-C-F treatments, respectively. Average soil surface residue levels in September 1992 before wheat planting were 4255, 3632, 1830, 0, and 7667 kg/ha for the NT, RT, SM, BF, and WW-C-F plots, respectively. Corn preplant residue levels in April 1993 were 2417 and 4250 kg/ha for the CC and CFW treatments, respectively.

Grain yields of the corn grown on those plots that were in winter wheat in 1992 (WW-C-F rotation) averaged 3164 kg/ha (50.4 bu/a) and those that were in corn in 1992 (CC rotation) averaged 2084 kg/ha (33.2 bu/a). Weed control in the continuous corn plots was a problem again in 1993 (Kochia, Russian thistle, and tickle grass). Corn silage yields (70% moisture) were 15.7 and 20.6 t/ha for the continuous corn and C-F-WW plots, respectively. Soil water use by corn averaged 2.6 cm from the 0- to 180-cm soil depth. Growing season precipitation (Apr 22 to Nov 2, 1993) was 34.0 cm for a total estimated ET of 36.6 cm. Water use efficiencies by corn were 57 kg/ha/cm for the continuous corn rotation plots and 86 kg/ha/cm for the corn grown on 1992 wheat stubble in the C-F-WW rotation plots.

INTERPRETATION: The four year (1990-1993) average winter wheat yields are 3254, 3143, 3155, 2942, and 2975 kg/ha for the NT, RT, SM, BF, and W-C-F treatments, respectively. The four year average corn yields are 3649 and 2209 kg/ha for C-F-W and CC treatments respectively. The corn yields in 1993 were acceptable considering the cool climatic conditions and erratic precipitation patterns. Silage yields are great enough to be of economic value in integrated crop-livestock systems.

FUTURE PLANS: The study will be continued as revised in the spring of 1989. The 1994 winter wheat crop should allow comparisons to be made between the WW-F and WW-C-F rotations. Wheat and corn yield data along with surface residue levels were summarized for the 1993 ASA meeting. A manuscript will be prepared as soon as all the laboratory analyses are completed.

EVALUATION OF MANAGEMENT PRACTICES FOR CONVERTING CONSERVATION RESERVE PROGRAM (CRP) LAND BACK TO CROPLAND

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CRIS: 5407-12130-003-00-D

PROBLEM: In response to the Conservation Reserve Program (CRP), which was initiated as part of the 1985 Food Security Act, 30.6 million acres of highly erodible cropland has been seeded to grass. After the eighth sign-up (June 14, 1989), Colorado had 1.8 million and Kansas 2.5 million acres in CRP. At the end of 10 years, the land may be converted back to cropland or left in grass. Information is needed on: 1) how to convert CRP grassland back to cropland while maintaining wind erosion protection; 2) fertility needs; 3) tillage needed to convert grassland back to cropland; 4) use of herbicides to initially kill the existing grass and control the grass in a no-till system; 5) use of more intensive cropping systems to enhance soil erosion control; and 6) improving productivity of grassland by N fertilization or introduction of legumes/grass species to encourage farmers to keep the land in grass. Research was initiated in the spring of 1990 at the Central Great Plains Research Station with the following objectives: 1) determine if CRP land can be converted to cropland using strictly no-till practices; 2) determine what effect tillage method used in converting CRP land to cropland has on crop yield, surface crop residue, and profitability; 3) evaluate initial weed problems (1st two years) and the need for herbicides/tillage for weed control purposes; and 4) determine if grass production on CRP land can be increased by N fertilization and/or introduction of legumes.

APPROACH: The study is located on a Weld silt loam soil which was in crop approximately 15 years ago and then was planted back to grass. Average grass-legume composition before treatments application was 80.1% crested wheatgrass, 13.6% blue grama, 1.7% sand dropseed, and 4.6% alfalfa. A split-plot, randomized complete block design with 3 replications is being used with tillage treatments as main plots and N rates as subplots. The treatments include:

1) Tillage: a) No-till (NT); b) Reduced till (RT); c) Conventional Till (CT)
2) N Rates: 0, 45, 90 kg N/ha (applied at or prior to planting)
3) Crop Rotation: Winter Wheat-Corn-Fallow
4) Grass with/without introduced alfalfa (established only in 1st year)

The grass on the third set of crop plots was sprayed with glyphosate and 2,4-D on the NT plots on May 4, 1992, after the grass greened up in the spring and was actively growing. The RT plots were initially sweep plowed on October 21, 1991 and then sprayed with glyphosate and 2,4-D on May 4, 1992. The CT plots were initially tilled on October 21, 1991. The plots were either tilled or chemically fallowed or both until winter wheat planting. Alfalfa was planted in the grass-alfalfa plots on May 5, 1990 at a rate of 2.2 kg seed/ha with a JD disk drill that had a grass-legume box attachment. Poor stands of alfalfa were established. Alfalfa was replanted in fall 1991, with good establishment in March and early April 1992, however, drought conditions during April and May of 1992 resulted in poor survival of the young seedlings.

Winter wheat (Tam 107) was planted (2,223,000 seeds/ha, 900,000 seeds/acre) with a Haybuster 1000 series disk drill on Sept 21, 1992 with 22 kg P/ha placed with the seed and harvested on July 6, 1993. The grass and grass-alfalfa plots were harvested on June 9, 1993 with a forage harvester that cut 11 sq. m from the center of each plot. Corn (Pioneer 3732) was planted on April 29, 1993 with a JD Maximerge planter (14,900 seeds/a) and harvested on September 27, 1993.

FINDINGS: Prior to planting in September 1992, preplant winter wheat surface crop residue measurements indicated that the NT, RT, and CT plots had an average of 81, 64, and 12% cover and residue dry weights of 1394, 1231, and 326 kg/ha, respectively. From April 3, 1992 until September 10, 1992 there was an increase in soil water content in the 180 cm soil profile of 5.0 cm in the CT plots and essentially no change in the RT and NT 1993 wheat plots. Soil water content was greater in the CT and RT than NT tillage treatments at planting. The 1993 winter wheat crop was dependent on precipitation received. Winter wheat yields averaged 3280, 3023, and 2478 kg/ha for the CT, RT, and NT treatments, respectively, when averaged over N rates. The lower yield for the NT treatment is a result of less available soil water to support the wheat crop during the drought period. There was not a significant winter wheat response to N fertilization in 1993. Average yields were 2838, 2980, and 3043 kg/ha for the 0, 45, and 90 kg N/ha rates, respectively. Soil water use by winter wheat was 19.6, 17.1, and 11.8 cm in the 0- to 180-cm soil depth in 1993 for the CT, RT, and NT treatments, respectively. Precipitation from April 1 to July 7, 1993 was 13.5 cm (5.3") for an estimated total ET of 33.1, 30.6, and 25.3 cm.

Grass yields (oven dry) were 606, 1225, and 1427 for the 0, 45, and 90 kg N/ha treatments, respectively. Alfalfa plus grass yields were 1128, 1436, and 1435 kg/ha for each of the respective N rates.

The 1993 corn grain yields (2nd set of plots) averaged 103, 772, and 1266 kg/ha for the CT, RT, and NT treatments, respectively. There was a negative grain yield response to N fertilization. Corn silage yields (70% moisture) were 8.2, 15.0, and 13.8 t/ha for the CT, RT, and NT treatments, respectively. These data indicate that the corn produced a fair silage yield, however, there was not sufficient soil water or growing season precipitation to produce a greater grain yield.

INTERPRETATION: The 1991, 1992, and 1993 yield and soil water data indicate that crop yields following grass will be very dependent on the amount of soil water storage that occurs during the previous fallow period. The data suggest that at least one tillage operation may be needed to kill the grass. The herbicide burned the grass down to the point it looked dead, but new shoots would re-establish from the crowns in the NT plots.

FUTURE PLANS: Plans are to harvest winter wheat from the 1st set of NT, RT, and CT plots in 1994, produce corn on the 3rd set of wheat plots, and fallow the 2nd set of wheat plots. Data collection will continue as planned in 1994. Plans are to prepare a manuscript on the wheat data for immediate publication. Much interest has been shown in this study by farmers, CASCD, and SCS.

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT-FALLOW

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CRIS: 5407-12130-003-00-D

PROBLEM: Economic strength, social stability, and a sustainable, environmentally acceptable agriculture throughout the Central Great Plains region depends on maximizing crop water use efficiency. Present cultural practices, using the winter wheat-fallow (WW-F) system, have resulted in extensive erosion by wind and water and a dependence on government subsidies. Saline seep development indicates inefficient water use in many areas of the Central Great Plains. Conservation tillage practices have enhanced infiltration of water into the subsoil. When this water is not used by crops, movement of soluble salts and agricultural chemicals into the ground water is accelerated or unproductive saline seep areas develop. National concerns for promoting an economically sustainable agriculture, which is environmentally sound, gives impetus to the need to develop dryland cropping systems that promote more efficient use of soil and water. Cropping systems that include spring crops in the rotation will also provide extra benefits by helping control winter annual grassy weeds, such as jointed goatgrass, downy brome, and volunteer rye. The study objectives are to: 1) evaluate crop rotations for more efficient water use and economic sustainability; 2) develop cropping systems that provide needed soil erosion control from wind and water; 3) reduce chemical inputs for weed, disease, and insect control in cropping systems through crop rotation; and 4) protect the soil resource base, environmental quality, and ground water quality with cropping systems that utilize water efficiently and reduce soil erosion.

APPROACH: The crop rotations were initiated in the spring of 1990 on a Weld silt loam soil at the Central Great Plains Research Station using a randomized, complete block design with 3 replications. Sufficient N is applied to each crop to optimize yield potential. Three tillage treatments are being compared for the winter wheat-fallow rotation: 1) complete-till (CT); 2) reduced-till (RT) and 3) no-till (NT). Because reduced- or no-till conditions are needed to efficiently store enough soil water between crops to make the more intensive rotations (other than WW-F) successful, a no-till or reduced-till system is being used with all other crop rotations. Tillage in these systems will be for the purpose of herbicide incorporation or to achieve occasional weed control. Crop rotations are shown in Table 1 with the 1993 and 3 year average yield results.

Table 1. Forage and grain yields for the various rotations and tillage treatments in 1993.

Rotation	Tillage	Biomass	Grain	Grain	Avg Yield
MONO-CULTURE		kg/ha	kg/ha	bu/a	(3 year)
1) M	NT	4246	1311	23.4	33.9 bu/a
2) ALF	NT	1851	----	----	2536 kg/ha
3) G-ALF	NT	2714	----	----	2473 kg/ha
2-YEAR ROTATIONS					
4) W-F	CT	7568	2539	37.8	37.1 bu/a
W-F	RT	8398	4380	65.2	52.1 bu/a
W-F	NT	8336	3807	56.7	45.6 bu/a
5) W-M	NT	5232	2078	30.9	31.0 bu/a
M-W	NT	5414	1875	33.5	36.0 bu/a
6) W-SC	NT	4006	759	11.4	15.2 bu/a
SC-W	NT	14.2 (t/ha)	----	----	18.6 t/ha
7) W-PEA	RT	7364	2682	39.9	30.6 bu/a
PEA-W	RT	2824	1208	18.0	19.3 bu/a
8) FM-C	NT	4824	----	----	4363 kg/ha
C-FM	NT	17.2(t/ha)	1197	19.1	29.8 bu/a
9) M-SUN(FM '91)	RT	5995	1817	32.4	31.7 bu/a
SUN-M	RT	7777	1476	47.1	42.8 bu/a*
10) C-SUN(FM '91)	RT	15.5 (t/ha)	1585	25.3	19.6 bu/a
SUN-C	RT	7247	1913	48.8	53.7 bu/a*
11) C-M	RT	15.3 (t/ha)	1565	25.0	25.7 bu/a
M-C	RT	4820	2019	36.0	34.0 bu/a
3-YEAR ROTATIONS					
12) W-C-F	NT	8098	3115	46.3	43.4 bu/a
C-F-W	NT	20.6 (t/ha)	2438	38.8	48.3 bu/a
W-C-F	RT	10171	4422	65.8	54.3 bu/a
C-F-W	RT	23.4 (t/ha)	2343	37.4	44.1 bu/a
13) W-C-M	NT	3554	927	13.8	19.8 bu/a
C-M-W	NT	15.7 (t/ha)	1382	22.2	46.1 bu/a
M-W-C	NT	5251	2474	44.2	36.9 bu/a
14) W-SAF-M	RT	4217	736	11.0	17.5 bu/a
SAF-M-W	RT	2871	484	9.6	18.1 bu/a
M-W-SAF	RT	4281	1291	23.0	26.0 bu/a
15) W-M-F	RT	10033	3720	55.3	44.4 bu/a
M-F-W	RT	5677	2442	43.6	43.1 bu/a
16) W-SOY-OP	RT	3526	110	1.7	14.5 bu/a
SOY-OP-W	RT	811	485	7.7	11.2 bu/a
OP-W-SOY	RT	1849	----	----	2120 kg/ha

Table 1. Continued.

Rotation	Tillage	Biomass	Grain	Grain	Avg Yield
4-YEAR ROTATIONS		kg/ha	bu/a	bu/a	(3 year)
17) W-C-M-F	RT	7613	4045	59.8	49.5 bu/a
C-M-F-W	RT	18.5 (t/ha)	2580	41.1	43.5 bu/a
M-F-W-C	RT	4180	1885	33.7	33.7 bu/a
18) W-M-C-F	RT	10811	4361	64.9	50.7 bu/a
M-C-F-W	RT	6794	2413	43.1	40.6 bu/a
C-F-W-M	RT	19.9 (t/ha)	2183	34.8	24.7 bu/a
W-M-C-F	NT	9955	4348	64.7	45.0 bu/a
M-C-F-W	NT	5892	1624	29.0	45.5 bu/a
C-F-W-M	NT	22.0 (t/ha)	1919	30.6	31.3 bu/a
19) W-C-SAF-F	RT	8136	3107	43.9	39.2 bu/a
C-SAF-F-W	RT	14.7 (t/ha)	892	14.2	34.1 bu/a
SAF-F-W-C	RT	4636	1174	23.3	19.2 bu/a
FLEXCROPPING					
20) FLEX(Corn)	RT	3738	485	7.8	954 kg/ha (gr)
FLEX(Corn)	NT	4095	1057	16.9	1290 kg/ha (gr)
Added in 1993					
21) Forage(FSorg)	NT	2822	----	----	----
22) FTRT-SUN-F	RT	2812	----	----	----
23) W-SUN-F	RT	5749	823	12.3	----
SUN-F-W	RT	3703	826	26.4	----

Symbols: ALF=alfalfa; C=corn; F=fallow; FSorg=forage sorghum; FTRT=forage triticale; FLEX=flexible cropping; FM=forage millet; G=grass; M=proso millet; OP=oats + Tinga Pea; Pea=Sirus Pea; SAF=safflower; SC=silage corn; SOY=soybean; SUN=sunflower; W=winter wheat; gr=grain; t=metric tons.

*Two year average for sunflowers, 1991 crop lost to gophers.

FINDINGS: All crops included in the study were planted as scheduled for harvest in 1993. Average 1993 grain/forage yields are shown in Table 1. Winter wheat yields were generally higher in 1993 than in 1992 and varied with the amount of soil water available in the rotation. Austrian Winter Pea stands were only fair in 1993, therefore grain yields (1208 kg/ha) were lower than in 1992. Soybean yields were poor again in 1993, therefore, plans are to plant Black Turtle drybeans in 1994. Corn grain yields varied greatly, depending on previous crop grown in the rotation and the amount of soil water available at planting. Safflower yields were lower than 1992 due to poor stands. Sunflower yields were higher than 1992. The alfalfa and grass-legume yields were limited by lack of water during the early part of the growing season. These are only three-year results and do not necessarily reflect the rotational effects at this point. A winter wheat-sunflower-fallow rotation was added in 1993 because of the importance of sunflowers to the region due to the construction of a processing plant at Goodland, KS. Extra plots were added to the north end of the experiment to allow for future expansion. A triticale-sunflower-fallow rotation was also added in addition to a FLEX forage plot where forage sorghum (hay grazer), oats, and triticale will be grown in rotation.

INTERPRETATION: This is the third year of yield data, therefore, no conclusions will be drawn at this time. Crop yields in 1993 were again very dependent on the amount of soil available water, especially the amount of soil water recharge that took place since the harvest of the previous crop.

FUTURE PLANS: All plots will be planted as planned for the 1994 crop year. The study will continue as planned. Upon completion of the 1994 harvest, plans are to prepare a manuscript on the yield results and projected economics. Another manuscript on changes in soil organic matter is in preparation.

CROPPED-LEVEL-TERRACES IN PASTURES

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CRIS: 5407-13000-002-00D

PROBLEM: New sustainable farming strategies that use an "integrated resource management" approach incorporating livestock with cropping systems are needed. It is through this approach that the level of purchased inputs can be potentially reduced and crop outputs can be better utilized. For example, livestock contribute manure as crop input and grazing reduces harvesting losses and better utilizes the biomass produced. Other proven farming practices can also be used to improve the farming success and long-term sustainability. For example, annual cropping utilizes precipitation better than rotations involving fallow. Water harvesting techniques like bench terraces also improve soil water storage and crop water use efficiency. So combining level terraces, strip cropping within a pasture and annual cropping rotations with integrated crop and livestock practices should inherently be a good, successful and sustainable farming practice. However, this type of farming is not commonly used and little or no literature exists on the combination of these four technologies and their interactions. The objective is to evaluate the hydrology, crop growth characteristics, soil properties and the practical aspects of this type of farming.

APPROACH: Research plots were established on level terraces, bench terraces and on natural slopes (3% and 6%) that were constructed in a native grass field with a water contributing width above each plot equal to three times the width of each level terrace (most optimum width for the contributing slope). Other treatment variables included with or without deep chiseling to improve infiltration. Runoff flumes and recorders are installed each year to measure the amount of water that runs onto the plot area and off of the level terrace and the natural slope plots in order to evaluate the water harvesting aspects of the terraces and the plot treatments. Plots that have no water contributing area (by using a diversion) are also included and are necessary to evaluate the crop growth and water use with only normal precipitation levels. The plots will be replicated three times. Soil samples from the top 5 cm (2 in) were taken in 1991 for soil organic matter analysis, and will be repeated at the end of the project.

FINDINGS: 1990: The terraces were constructed and plots established in May and June. The plots were planted to grain sorghum in June with poor emergence and yields (<1300 kg/ha (<20 bu/ac)) due to dry surface soil conditions. **1991:** Corn was planted no-till in the plots with 73 kg/ha (65 lb/ac) of nitrogen applied as starter with the planter and as NH3 side-dress chiseled. No rainfall was harvested during the spring and summer of 1991. Because of low rainfall after mid-June, potential grain yields were low so the corn was cut for silage August 22-23, 1991. Silage yields ranging from 6.7 to 19.9 Mg/ha (3 to 9 tons/ac), at 70% moisture content. The deep-chisel subplots were deep chiseled to 38 cm (15") in the fall of 1991, as they were in 1990. The grass pasture was not grazed but the areas between the terraces were mowed

and baled late June 1991. The 3% sloped area produced 1040 kg/ha (930 lb/ac) and the 6% sloped area produced 627 kg/ha (560 lb/ac) of hay. **1992:** Grain sorghum was planted no-till with no fertilizer applied. All plots were cultivated once 7-23-92. Grain sorghum yields were greatest on the bench terraces, with the chiseled plots on the level terraces only slightly less. Runoff was recorded from several rainfalls in 1992. Grain sorghum yields were greater on the 6% slope than the 3% slope for all plots. During mid-June, the grass between the terraces was mowed and baled but only yielded 7 to 31 kg/ha (16 to 67 lb/ac). On 10-23-92, the chisel subplots were chisel-plowed 25.4 cm (10") deep, and the edges of the cropped areas and the terraces were mowed to prevent differences in snow catch between plots. **1993:** Corn was planted no-till with 67 kg/ha (60 lb/ac) of nitrogen applied side-dress injected at the time of planting. Runoff was again measured from rainfalls in 1993. Silage yields and grain yields were harvested. Silage yields ranged from 8.0 Mg/ha (3.6 ton/ac) to 29.2 Mg/ha (13.0 ton/ac), at 70% moisture content. Grain yields were similar to those in 1992. The pasture between the terraces was mowed and baled during June, and hay yields were approximately 335 kg/ha (300 lb/ac) for both the 3% and 6% slopes. The chisel subplots were deep-chiseled 38 cm (15") on Nov. 2, 1993. Combined grain yields for 1992 and 1993 are shown below.

1992 + 1993

Combined

Grain Yield

(kg/ha)

Terrace/Slope		Subplot type	3% slope	6% slope	
Normal Slope	diversion	2255	2499		
"	"	-----		2389	2286
"	"	chiseled		1953	3388
Level Terrace	diversion	3157	3540		
"	"	-----		3646	4441
"	"	chiseled		3899	5476
Bench Terrace	diversion	3996	4295		
"	"	-----		4349	5198

Maintenance: The bench terrace berms were sprayed with 2,4-D herbicide during early June 1991, late August 1991, mid-May 1992, mid-June 1992, and mid-June 1993 to control broadleaf weeds.

INTERPRETATION: With the third and fourth year that the terraces and plots have been established, significant and real treatment or plot effects became apparent. The level terraces produce grain yields greater than the normal slope and almost as great as bench terraces. Deep chiseling increased yields over non-chiseled plots. The 6% slope harvested more water than the 3% slope, which resulted in greater yields on the level and bench terrace plots.

FUTURE PLANS: The results so far will be published in an agricultural journal and in farmer publications, and presented at meetings. This project should be continued for at least two more years, in order to graze the pasture with cattle for a few weeks during 1994 and 1995. Electric fencing will be used to block off ungrazed cropped areas for comparing infiltration differences with and without cattle. Infiltration rates can be determined with a sprinkler infiltrometer.

WHEEL-RIDGE-TERRACE STRIP-CROP FARMING

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CRIS: 5407-13000-002-00D

PROBLEM: New farming techniques and strategies are needed that are sustainable. Cropping practices that use more spring and summer annual crops and use less fallow periods can better utilize the precipitation that falls in the west Central Great Plains. At Akron Colorado, almost two-thirds of the annual precipitation (82 year average) occurs during the late spring and summer months of May (3.04"), June (2.51"), July (2.67") and August (2.03"). During the fallow period, most of the precipitation can be lost to the atmosphere as natural evaporation after a rainfall event (due to no transpiring growing plants) or due to enhanced evaporation due to tillage operations that are done a week or so after a rainfall because the rain causes new weeds to sprout. Therefore, the practice of fallowing the land, although saving moisture from an additional winter's snowfall and being a very successful long-time farming practice, has a low precipitation use efficiency (PUE) when compared to more intensive annual cropping.

Annual cropping with no fallow periods, on the other hand, is a marginal farming practice in this region due to the low total annual precipitation and is only successful with reduced tillage. However, reduced tillage farming may have more problems with weeds and may require more management. All of these concerns have been deterents to the adoption of reduced tillage farming. Therefore, a farming practice using annual cropping (to better use precipitation) but less constrained by the limited total precipitation could be potentially more successful than traditional crop-fallow rotations. Research in the late 60's and early 70's showed that water harvesting can increase total crop production per total area over conventional farming production during high precipitation years. The objective of this project is to determine if a wheel-ridge-terrace method of farming is a more sustainable long-term way to produce annual crops.

APPROACH: This project will used two separate sets of experimental plots, both using a randomized block statistical design. The two sets were:

1. A wheel-ridge-terrace (WRT) production area using three annual crops grown each year and replicated four times. Plot size is 30' x 100'. The WRT replaces the 2nd and 5th rows when using 6-row equipment, so that 2/3 of the land surface is cropped, and 1/3 harvests water. These plots were established the fall of 1990.
2. Soil profile comparison (SPC) plots to compare a) wheel-ridge-terraced, 4 of 6 rows cropped (W4), b) ridged-tilled, 4 of 6 rows cropped (R4) and c) conventional flat surface, 4 of 6 rows (F4), d) flat surface 6 of 6 rows (F6) cropped, and e) flat, 6 of 6 rows, fallowed once every three years. These plots were replicated four times. Plot size is 15' x 120', and were established the spring of 1990.

Soil organic matter, soil moisture (neutron attenuation), growth stage, soil bulk density and grain yield were measured in these plots.

FINDINGS: Corn was grown in the SPC plots in 1991 and 1993, and grain sorghum in 1992, and the respective grain yields and the three-year totals are:

		Grain yields (kg/ha)				
Year	Crop	W4	R4	F4	F6	F6-fallow
1991	Corn	3242	2553	2187	2009	2023
1992	Sorghum	2847	2937	2182	3341	----
1993	Corn	2697	2427	2063	1631	2402
All	Both	8786	7917	6432	6982	4425

Grain sorghum was grown in the SPC plots in 1990, but the W4 and R4 yields were not representative due to building and shaping the surface profile of these two sets of plots in the spring of 1990. The F6-fallow plots were fallowed in 1989.

Corn, soybeans, and sunflowers were grown in the WRT plots in 1991, 1992 and 1993. Corn population subplots were planted with 4 plant populations, and 2 varieties (91 and 100 day maturities). Corn grain yields on a total area basis ranged up to 5193 kg/ha (83 bu/ac). Optimum population was 33333 pl/ha (13333 pl/ac) on a total area basis, and 50000 pl/ha (20000 pl/ac) on a cropped area basis. Soybean grain yields averaged 891 kg/ha (13.3 bu/ac) in 1991, 1294 kg/ha (19.1 bu/ac) in 1992 and 1519 kg/ha (22.6 bu/ac) in 1993, all on a total area basis. Sunflower yields averaged 1219 kg/ha (1088 lb/ac) in 1991, 1213 kg/ha (1083 lb/ac) in 1992 and 1635 kg/ha (1460 lb/ac) in 1993, all on a total area basis.

INTERPRETATION: The soybeans appear to benefit most from the water harvesting and wind protection aspects of the wheel ridges, as evident by much greater than normal yields on a total area basis. It would be preferable to have the wheel ridges farther apart so that less land is out of production but with the same benefits. In future research, I suggest using 3.3 m (10 ft) ridge spacing, planting in narrower rows, and planting closer to the wheel ridges in order to have a much higher percentage of the total area cropped, all of which should help to improve total area yields. The corn population part of the WRT plots showed that corn populations on a cropped area basis need to be increased.

FUTURE PLANS: The field part of this experiment is completed. The data will be further analyzed and the results will be published in agricultural journals and farmer publications, and presented at ag. technical meetings.

CROP RESIDUE DIFFERENCES WITH TILLAGE

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CRIS: 5407-13000-002-00D

PROBLEM: Not enough data exists on the reduction and decomposition of crop residues due to time, tillage and weather factors. The Soil Conservation Service in Colorado has targeted this issue of crop residue changes through a season as an important issue for the proper determination of residue levels in regard to the Conservation Compliance program within the Farm Bill. As dictated in many individual farm conservation plans, certain residue cover levels must be maintained. There is still much uncertainty as to what amount of tillage can be done between harvest of one crop and the planting of the next crop, and still maintain enough residue cover during high wind periods. Rainfall and the resulting surface soil moisture can have a significant effect on the rate of residue decomposition. Rates of decomposition determined in the climatically-wetter regions of the eastern half of the U.S. are probably not appropriate for the semi-arid regions of the western Great Plains. The objective of this project is to measure changes in crop residues for four crops, different tillage systems, and different rainfall levels (simulated with irrigation).

APPROACH: Corn, soybean, sorghum and winter-wheat residues from crops grown in previous years within a solid-set irrigation system will be used for this project which was started in 1992. None of the cropped areas are tilled after harvest. Beginning residue levels (mass and percent cover) are measured. Plots are established across an irrigation gradient to simulate different rainfall water regimes. Different strips of tillage plots across the gradient are established as soon as possible in the spring. The corn, sorghum and winter-wheat residues have tillage treatments of 1. chisel, disk (CD), 2. disk only (DD), 3. disk, sweep-plow (DS), 4. chisel, sweep-plow (CS), 5. sweep-plow only (SS) and 6. non-tilled (NT). The second operation is also the third and subsequent tillage operations. The soybean residues have tillage treatments of 1. disk (D),
2. sweep-plow (S), 3. rotary-hoed (R) and 4. non-tilled (N). The residue plots are not cropped the year that residue mass and percent cover are measured during the year. Rainfall and irrigation amounts are measured with catch cans. Specific details of the tillage operations (type, depth, speed,...) will be noted and recorded.

FINDINGS: In 1993, corn and soybean residue areas were used for this project and the fields were left untilled in the fall of 1992. Plots were established in the spring of 1993. Residue measurements were taken eight times from May 19 to Sept. 3, 1993. The plots were tilled four times on May 20, June 28, July 29 and Sept. 2. For the tillage treatments, plots were chiseled 25 cm (10"), disked 13 cm (5") or sweep-plowed 8 cm (3") deep. **Soybeans:** Initial soybean residue levels on May 19 were 36% cover and without any tillage, decreased to 9% by Sept. 1 (lost to the wind and/or to animals?). Soybean residues can be sweep-plowed one time and leave

close to 30% cover, but 1 disking leaves only 10% cover. The first rotary-hoeing operation left 33% cover, but subsequently declined similar to the non-tilled plots. The rotary-hoeing operation did not adequately control weeds so it can not substitute for spraying herbicides in previously non-tilled soil. **Corn:** Corn residues were used from three different maturity-length corn hybrids: 91, 100 and 110 day relative maturities. Again, as in 1992, corn residue can generally be sweep-plowed 3 times and still leave close to 30% cover. The disk only plot had dissimilar results among corn hybrids. The 110-day hybrid corn residue needed 3 diskings before percent cover dropped below 30%. The 91-day and the 100-day hybrids needed only 1 and 2 diskings respectively before their percent cover dropped below 30%. However, these three hybrids also started out with different levels of non-tilled residue on May 19, 1993, namely: 70%, 80% and 90% for the 91, 100 and 110 day hybrids, respectively. All 3 corn hybrid residues left in non-tilled plots lost approximately 25% total residue cover from May 27 to August 9, 1993. The other 3 tillage treatments can be compared to the disk-only and sweep-plow-only treatment. The chisel-followed-by-diskings treatment had residue levels similar or slightly-less than the disk-only treatment. The chisel-followed-by-sweep-plowings treatment had residue levels similar or slightly-less than the sweep-plow only treatment.
The disked-followed-by-sweep-plowings treatment had residue levels only slightly less than the sweep-plow only treatment.

INTERPRETATION: The sweep-plow is a good implement for maintaining adequate residues in corn, and for a 1-time tillage in soybeans. A sweep-plow or an undercutter could be a good alternative tillage implement for irrigated cropping systems because it could open up more options for timing herbicide and tillage operations. The destructiveness of a disking operation in irrigated corn residues may be dependent on particular corn hybrids. The disking operation wasn't nearly as destructive when it is the first operation, and is much more destructive to corn residues as the second and/or subsequent tillage operation. If disking or chisel-plowing is the first tillage operation, as long as the subsequent operations are sweep-plowings, residue cover levels will be similar or only slightly less than if the field had been sweep-plowed only. What is most interesting is that both the non-tilled soybean and corn residue areas lost 25 to 27 percent residue cover over the summer months. One would have to speculate that the standing corn residues were grazed by deer and other animals, and the loose soybean residues are simply blown away by the wind or are also consumed by animals.

FUTURE PLANS: These experiments can be repeated in 1994 using corn, soybean, sorghum and winter-wheat residues. The information will be made available to the SCS and will be published in agricultural journals.

DRILLED DWARF-CORN PRODUCTION STUDY

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Central Plains Resources Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Dwarf corn hybrids may provide another important alternative for dryland corn production in the west-central Great Plains region of the United States. Research on plant populations, row spacing and grain yield is needed to determine optimum production practices for dwarf hybrids for this region. The characteristics of corn growth as a function of population and row spacing needs to be measured to understand how optimum yields are obtained. These hybrids can be planted with a grain drill and combine harvested with a grain platform head, which has the economic advantage for traditional wheat farmers of not having to buy a row crop planter or a corn head for their combines. The agronomic growth characteristics and the practical, logistical aspects of farming dwarf corn hybrids need to be evaluated.

APPROACH: A commercially available dwarf corn hybrid, Cargill 1077 was grown in 1991, 1992 and 1993. This dwarf corn has a rated maturity of 77 days for the north-central United States. Row spacing was 7" in 1991, and 16" in 1992 and 1993, and also ranged from 8" to 32" in additional row-spacing experiments in 1993. These dwarf corn plots were located on land that was winter wheat the previous year, and were planted no-till into the standing wheat stubble. The corn was planted mid-May and also topdressed with at least 67 kg/ha (60 lb/ac) of N, as ammonium nitrate.

FINDINGS: In 1991, the dryland dwarf corn grain yields ranged from 2800 kg/ha (45 bu/ac) to 3770 kg/ha (60.2 bu/ac). In 1992, the grain yields ranged from 4402 kg/ha (70.2 bu/ac) to 4792 kg/ha (76.4 bu/ac). In 1993, the grain yields ranged from 3857 kg/ha (61.5 bu/ac) to 4402 (70.2 bu/ac). Other growth characteristics of the dwarf variety were:

Growth Characteristic	1991	1992	1993
Ear length	5 to 15 cm (2 to 6")	7 to 14 cm (3 to 5.5")	10 to 15 cm (4 to 6")
Shank height 25 to 43 cm	38 to 61 cm (10 to 17")	33 to 48 cm (15 to 24")	(13 to 19")
Leaf area index	2.1 to 2.35	---	---

Also in 1993, forage samples were taken to determine silage yields, and samples taken on Aug. 31, 1993 averaged 32000 kg/ha (14.3 tons/ac) at 70% moisture content, for the 110000 pl/ha (44000 pl/ac) plots.

Economic analysis was conducted to determine where the marginal cost of the seed equaled the marginal revenue of the harvested grain. In 1991, optimum final dryland population would have been 100 to 106 thousand pl/ha (40000 to 42500 pl/ac) for $2 to $3 corn. In 1992, dryland yields increased linearly with population. In 1993, optimum plant populations were 100 to 107 thousand pl/ha (40000 to 43000 pl/ac). Also in 1993, grain yields of the dwarf corn decreased with increasing row spacing. In these separate plots, grain yields were 3200 kg/ha (51 bu/ac) at 20.3 cm (8") row spacing, and decreased to 2070 kg/ha (33 bu/ac) at 81 cm (32") row spacing.

Farming practices: In 1992 and 1993, the dwarf corn was planted with a drill with a fluted metering cups and with 20 cm (8") opener spacing. Every other opening in the seed box of the drill was covered so that 40.6 cm (16") rows were planted in 1992. This drill and row spacing had much better seed distribution along the row, than in 1991 where a drill with a paddle wheel and gate type metering and 18 cm (7") row spacing was used. Because the ear shank height was so low in 1991, stubble heights were generally less than 10 cm (4") and much of the residue blew off the plots during the winter and snow depths were much less than in conventionally harvest corn rows. With no tillage after harvest, only 38% residue cover was measured in the spring of 1992. In the spring of 1993, the dwarf corn stubble had 55% residue cover.

INTERPRETATION: Based on 1991 and 1993 results, the Cargill 1077 dwarf hybrid should be planted at dryland populations between 100,000 pl/ha (40,000 pl/ac) and 107,000 pl/ha (43,000 pl/ac), and it shows good potential as a alternative annual crop. The dwarf corn has an advantage of drying down much sooner. It was at 15 percent grain moisture content by Sept. 20 in 1991, by Oct. 13 in 1992, and by Sept. 25 in 1993. The year 1992 had a much cooler summer and times to maturity of most crops was extended by as much a one month. The dwarf corn was planted in mid-May for all three years.

Combine harvesting the drilled corn with a reel with parallel, vertical bats caused some of the ears to be knocked off the plant onto the ground, especially for ears that were still pointing upward. A more traditional reel with fixed bats and/or with wider bats, similar to those used for sunflowers, would probably cause less ears to drop. A sunflower head with pans with the same row and pan spacing may also reduce ear drop. The new stripper-type grain heads were determined to not be workable for harvesting the dwarf corn. However, stripper reels with larger slots are being developed for larger headed crops like grain sorghum, which may also work for dwarf corn. Harvesting with a stripper head could potentially leave ear-shank heights of standing residue in the field, which should greatly increase snow catch and reduce potential wind erosion.

FUTURE PLANS: The row spacing plots should be repeated one more year with this dwarf corn hybrid. The results of this project are being combined with water stress and water relations work on this dwarf corn hybrid that was started in 1993 by Dr. David C. Nielsen, ARS - Akron CO, and this project will be turned over to him. The results will be published in regional popular publications, and an agricultural journal.

IRRIGATED CORN POPULATION-YIELD STUDY

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Central Plains Resources Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Many agronomic factors and cultural practices can influence corn grain yields. Plant populations have a direct effect on potential corn yields. Much uncertainty exists among irrigated farmers as to what is optimum plant population. Optimum plant population for each corn hybrid can be different. Even among hybrids with the same maturity, optimum plant population can vary due to vegetative and reproductive growth differences. However, farmers will typically use a particular corn hybrid for many years. If the optimum plant population for a certain hybrid can be determined during the first 1 or 2 years of use, then at least that variable becomes known and is no longer a worry or concern for the farmer. The objective of this project is to analyze the physical components of corn plants that determine final grain yield (i.e., leaf area, number of stalks, ears and kernels, and kernel mass) and how these components interact as a function of population. These component functions can then be used to determine optimum plant population, potential grain yields, and what components are most significant for producing high yields.

APPROACH: Three corn hybrids (Pioneer 3779, 3714, 3475 with relative maturities of 98, 102, 106 days to black layer development, respectively) were planted at four different plant populations and replicated four times. The corn was grown at two sites on sandy loam and silt loam soils and was irrigated to fully replace crop evapo-transpiration losses. Physical characteristics and yield components were measured and included leaf area at full cover and the following at harvest: stem count, ear count (1st & 2nd ears), number of rows and columns of kernels per ear (1st & 2nd ears), average kernel mass, yield, moisture content and test weight. The relationships between these variables were graphed, analyzed and mathematical functions developed for them. The functions are then used to predict grain yield, optimum plant population and to determine which components are most significant and critical to producing high yields. Note: Row spacing was 76 cm (30") for all of these corn plots in this experiment.

FINDINGS: Analysis is ongoing for the yield component data from 1992 and 1993. This experiment was repeated again in 1993 for the plots at the sandy loam site because they were hailed out in June of 1992. Corn was planted at seeding populations of 55000 to 87500 plants/hectare (22000 - 35000 plants/acre). From the analysis so far, potential grain yields as great as 11900 kg/ha (190 bu/ac) are possible for the elevation and seasonal growing degree days near Akron CO. Optimum plant populations for irrigated corn can range from 67000 to 82000 plants per hectare (27000 to 33000 pl/ac). Water use efficiency, expressed as water/grain mass ratio, ranged from 570 to 700. Leaf area was not limiting for populations greater then 50000 pl/ha (20000 pl/ac) where leaf area index (LAI) values were greater than three.

Sensitivity analysis: The number of second ears goes to zero, and the ratio of first ears to stems approaches one as populations increase toward 75000 pl/ha (30000 pl/ac). The ratio of first ears to stems decreases with decreasing population due to more tiller stems. On the first ears, the number of rows of kernels (ear length) decreased with increased population. On the second ears, rows of kernels was essentially constant at 30 rows. Columns of kernels (ear diameter) was not dependent of population and had an average value of 15 for both first and second ears. Kernel mass was surprisingly not dependent on plant population and averaged 0.249 g per first-ear kernel and 0.199 g per second-ear kernel. Multiplying the actual data values of number of ears, rows and columns of kernels, and kernel mass together predicts grain yields within 10%.

INTERPRETATION: The most significant and sensitive component to grain yield is the number of first ears. The ratio of first ears to stems increases to a value of one near the optimum population and then decreases due to greater numbers of earless stems at higher populations. Ear length (number of rows of kernels) is another important variable that affects final grain yield. Number of second ears is not that important for maximizing yields because at optimum populations, their numbers are small, their ears are much shorter and kernel size is smaller, too. This information will allow component analysis and calculations to pinpoint the optimum stem population for maximum yields or maximum profits.

FUTURE PLANS: The results will be written up and presented at the national agronomy meetings, in a crop production journal, and as farm magazine articles.

DRYLAND PRODUCTION OF RASPBERRIES WITH CROSS-LINKED POLYACRYLAMIDE (CLP) AND WEED/EVAPORATION BARRIERS

David C. Nielsen
Central Plains Resource Management Research Unit

CRIS : 5407-13000-002-00D

PROBLEM: Diversifying agricultural production is becoming more important for agricultural productivity and sustainability. An alternative crop that may have potential as a cash crop in the central Great Plains is raspberries. The development and marketing of CLP, which has the ability to absorb and store large quantities of water, make the production of rainfed raspberries a possibility if sufficient water can be harvested from adjacent non-cropped areas and retained in CLP for later use by raspberry plants. Further enhancement of the benefit from natural precipitation can come from the suppression of weeds and evaporation with a polypropylene weed barrier. Various bed construction factors, rates of CLP, types of weed barriers, catchment area to bed area ratios, longevity of weed barriers and CLP, rainfall/yield relationships, costs of production, and revenues from sales of product will need to be investigated. The objectives of the current study are:

1. Determine if raspberries can be successfully produced under non-irrigated, rainfed conditions with the use of CLP and weed/evaporation barriers.

2. Determine the optimum rate of CLP necessary for successful production of non-irrigated, rainfed raspberries.

3. Determine the relative contribution to yield of CLP and weed/evaporation barrier, and combinations of the two.

APPROACH: A site was selected on a grassed rangeland area with approximately 3% slope (sloped to the SW). Three level-bench terraces were constructed on the slope. Each bench was 5' wide by 96' long, with an uphill water catchment and runoff area of 10' by 96' that was left in grass. Each bench was used for one replication of the experiment.

A split plot, randomized complete block design with presence of DeWitt Sunbelt weed barrier as main plots and level of CLP as subplots was established Three levels of CLP were evaluated (0, 1, and 4 lbs CLP/plant). The CLP was incorporated through the 0-10" surface soil layer using a rototiller on 4 May 1993. The weed barrier was installed on 5 May 1993 and had openings of 12" by 18" spaced on 24" centers cut into it to allow for raspberry planting and growth. The weed barrier was staked down with fabric pins. Raspberry plants (cultivar "Heritage") were transplanted on 7 May 1993, with plants spaced 24" apart in the center of the 5' wide bench.

Plant heights were measured on 20 August and 12 October by measuring the length of the tallest cane in each of the four center plants in each plot. Leaf area was measured with the

LAI-2000 plant canopy analyzer on 10 September. Raspberries were harvested by hand-picking all ripe berries on the four center plants in each plot, twice each week from 14 August to 15 October.

FINDINGS: The weed barrier increased plant height on both dates, with the difference between the two barrier treatments increasing with time (although the differences in height between barrier treatments was not statistically significant). The CLP treatments increased plant height with the 1 lb/plant rate, but decreased plant height with the 4 lb/plant rate. CLP treatment differences were statistically significant. The plants grown with the weed barrier had approximately 18% greater leaf area than the plants grown without weed barrier. Plants grown with the 4 lb/plant CLP rate had the lowest amount of leaf area. The barrier treatment differences were statistically significant; the CLP treatment differences were not.

Production for all treatments peaked on August, with a rapid decline in production at the end of August. Total production over the 2 $^{1}/_{2}$ month picking period was greatest in the plots without CLP in both barrier and no barrier treatments. The CLP effect was statistically significant. Production was least in the plots with 4 lb/plant of CLP in both barrier and no barrier treatments. For both the 0 and 1 lb/plant CLP treatments the plots with barrier yielded more than the plot without barrier. Averaged across CLP treatments, the barrier resulted in 21% higher yields than the no barrier treatment, although this difference was not statistically significant. Averaged across barrier treatments, the 0 lb/plant CLP treatment yielded 24% higher than the 1 lb/plant CLP treatment, and 224% higher than the 4 lb/plant CLP treatment. The effect of the weed barrier in reducing evaporative losses and increasing the effectiveness of small precipitation events can explain the higher yields for plant grown under the barrier. More than 22% of the total precipitation from May through October came in amounts less than or equal to 0.25". These small rainfalls accounted for more than 62% of the total number of precipitation events.

INTERPRETATION: Caution should be used when reviewing the yield data for 1993. During this establishment year the plants are developing root systems and dealing with transplant shock, so the yield results may not mean too much relative to the long-term yields as affected by the barrier and/or CLP. We currently not have an explanation relative to the significant yield reductions that appear to be the result of the CLP treatments.

FUTURE PLANS: The very wet conditions during October have put the beds in very good condition for 1994. We expect further improvement in the water status of the beds following winter and spring as the CLP continues to collect precipitation and runoff. We plan to continue our measurements of plant development (height and leaf area) and yield.

NON-WATER-STRESSED BASELINES FOR ALTERNATIVE CROPS

David C. Nielsen
Central Plains Resource Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Developing knowledge regarding the effects of water stress on plant growth, development, and yield is crucial to evaluating the feasibility of production of various alternative crops for the central Great Plains. Infrared thermometry and the Crop Water Stress Index (CWSI) offer a simple, quick, and proven method of quantifying water stress. But the method requires knowing crop-specific non-water-stressed baselines which define the relationship between vapor pressure deficit and the canopy minus air temperature differential under well-watered conditions. Published non-water-stressed baselines are not available for many alternative crops. The objectives of this study are:

1. Determine non-water-stressed baselines for alternative crops
2. Determine in these baselines change with crop growth stage
3. Determine if CWSI computed from the generated baselines provides a useful measure of crop water stress.

APPROACH: Plots of canola, crambe, Indianhead lentil, Austrian winter pea, Tinga flat pea, black turtle bean, blue speckled tepary bean, sunflower, and dwarf corn were established under sprinkler irrigation. Irrigations were applied weekly to replace evapotranspirational losses determined from neutron probe readings of soil water content. Measurements of canopy temperature, air temperature, and vapor pressure deficit were taken at 30-min intervals from approximately 1000 to 1600 MST. Canopy temperature measurements were made from the southeast and southwest corners of each plot. Measurements were made only under clear sky conditions.

FINDINGS: Only canola, crambe, lentils, Austrian winter peas, and dwarf corn were measured consistently in 1993. All crops showed fairly consistent linear baselines throughout the measurement period from 21 June to 27 July, with no significant shifts in baseline slope and intercept after full cover development.

CROP	SLOPE	INTERCEPT	r^2
Canola	-2.49	1.88	0.81
Crambe	-2.53	2.52	0.77
Lentils	-2.21	2.10	0.73
AW Peas	-3.21	4.33	0.89
Dwarf Corn	-1.35	2.46	0.50
Sunflower	-1.07	2.62	0.60
BST Bean	-2.65	2.77	0.43
TF Peas	-3.88	5.78	0.89

INTERPRETATION: The stable nature of the baselines suggest that infrared thermometry and CWSI will be a good method for quantifying water stress in future research on these alternative crops in dryland cropping systems.

FUTURE PLANS: This experiment will be run again during the 1994 growing season. We will attempt to acquire the baseline data for the beans, Tinga flat pea, and sunflower that we missed in 1993. We will verify the baselines acquired during 1993 on the other crops. We will begin looking at how CWSI calculated for alternative crops using the new baselines responds to water stress conditions under dryland cropping situations so that the value of the maximum temperature differential between canopy and air under non-transpiring conditions can be determined.

TIMING OF WATER STRESS EFFECTS ON CANOLA PRODUCTION

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Central Plains Resource Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Canola is an alternative new crop that may have potential for the central Great Plains, but much is unknown relative to the growth and production potential of canola in this area. Unknowns associated with canola are how water stress at various growth stages affects growth, water use, rooting patterns, yield, and yield components. Knowledge regarding the sensitivity of canola to water stress at various growth stages can help to determine if it will be suited for this environment.

The objectives of this experiment are to determine effects of timing of water stress on:

1. Yield and yield components of canola, thereby identifying sensitive or critical growth stages relative to time of water stress.
2. Water use and water use efficiency.
3. Plant growth (height, leaf area development, rate of development).
4. Rooting patterns and water extraction

APPROACH: Twelve small plots (approximately 2.7 by 2.7 m) that are covered by an automated rainout shelter during precipitation events are used for this experiment to completely control timing and application of water. Canola (cv. Westar) was hand-seeded into the plots at a rate of 25 lbs/acre into rows spaced 12" apart, with eight rows per plot. Emergence occurred on 29 April 1993 and the stands were thinned to a population of 442,000 plants/acre on 19 May 1993 The 12 plots were divided into four water application treatments and three replications in a randomized complete block design. The four treatments (Table 1) are timing of water application, with all plots receiving the same amount of water over the growing season but at different times.

Table 1. Treatments for effect of timing of water stress on canola production

Treatment No.	Vegetative	Reproductive	Grain-filling
	Fraction of total water applied		
1	1/3	1/3	1/3
2	1/2	1/2	0
3	1/2	0	1/2
4	0	1/2	1/2

The growing season was estimated to be 15 weeks in duration, based on observations of Vigil during the 1992 growing season. Long-term average precipitation during the 15-week growing season is 9.17". This amount of water was applied in equal weekly amounts as designated by the treatments in Table 1. All treatments began with the 0-90 cm soil profile at near field capacity .

Measurements of soil water content were made with a neutron probe at 0.45, 0.75, 1.05, 1.35, and 1.65 m, and by time-domain reflectometry in the 0-0.30 m layer . These measurements were made at the beginning of the experiment, and at the end of each 5-week period. Evapotranspiration was calculated by the water balance method, and rooting depth was estimated from observations of soil water depletion.

Leaf area index, crop height, and plant growth stage were measured from time to time to quantify water stress effects on plant growth and development. Final grain yields were taken on 29 July and 04 August from a 2 m by 4 row area from the center of each plot to quantify water stress effects on plant productivity. Seed was analyzed for oil content to determine water stress timing effects on seed quality. Data were analyzed by standard ANOVA procedures for a randomized complete block design.

FINDINGS: The water treatments caused differences in rate of plant development. Water stress early in the growing season delayed plant development, but when the stress is removed canola can develop rapidly. Water stress late in the growing season hastened plant development.

Differences in plant height were not evident until the middle of June when bolting occurs. Tallest plants were found in Treatment 2, while Treatment 4 showed the shortest plants. Treatment 4 plants made some recovery in plant height late in the season as the early season water stress was removed. Treatment 3, which was stressed during the second five weeks of the growing season (June and first week of July) did not grow as tall as the other treatments.

It is unfortunate that no leaf area measurements were obtained during the first 5 weeks of the experiment. Visual observations indicated that severe restrictions of leaf area development occurred in Treatment 4 due to lack of water early in the growing season. When water was applied during the last 10 weeks of growth, this treatment increased its production of leaves and was able to maintain higher levels of leaf area longer than the other treatments. Maximum LAI values ranged from 3.02 to 4.47.

Total seasonal water use (evapotranspiration, ET) was significantly different among the different water stress timing treatments. The highest water use occurred with Treatment 2, where all of the water was applied during the first 10 weeks of the growing season. This seems reasonable in light of the higher leaf area development for this treatment during the vegetative and reproductive periods. The lowest water use occurred in Treatment 3, where no water was applied during the second five weeks of growth.

Seed yield was not significantly different among water stress timing treatments, although the trend appears to be for a large reduction in yield when water stress occurs during the last 5 weeks of growth (Treatment 2). Yields in this treatment were 62% lower than yields from Treatment 4, where water stress occurred during the first five weeks of development. The overall low yields for all treatments may be a result of the late planting date. The low yields for Treatment 2 are a result of significantly lower numbers of branches per plant and pods/branch. Seed weight was not significantly affected by water stress timing treatments.

Water use efficiency was not significantly different among water stress timing treatments, although the trend appears to be for a large reduction in WUE in Treatment 4, as a result of the already described highest water use and lowest yields of any of the treatments.

All treatments extracted about the same amount of water from the 75 cm depth. At the lower depths, Treatment 3 extracted less water than the other treatments indicating less prolific root development. This may indicate that water stress during the second five weeks of growth imposes a limitation to root development that is not overcome when water conditions later in the season improve. The deepest rooting appears to take place when water stress is small during the entire growing season (Treatment 1) or during the first ten weeks (Treatment 2). Unfortunately, as seen in the yield data, this increased rooting depth and ability to extract water from lower soil depths noted for Treatment 2 did not stop major yield reductions due to stress during the last 5 weeks of development.

INTERPRETATION: From this first year of data we can make several conclusions:

1. Canola appears to be most sensitive to water stress during the last 5 weeks of development when the plants are forming pods and filling seeds.

2. Canola appears to recover very well from early season water stress. These stressed plants have the ability to recover leaf area, form flowers, set pods and fill seeds when the water stress is removed. Initial delay in development is also overcome as water stress is removed.

3. Water stress during the second five weeks of development appears to inhibit root development below 90 cm, but this does not have a significant impact on yield. Soil water extraction is greatest when plants are stressed during the last five weeks of development, but significant yield-reducing stress can still occur.

4. Total water use can vary significantly with timing of water application. The highest water use occurred when plants were stressed during the last five weeks of development, and the least water use occurred when plants were stressed during the second five weeks of development.

5. Water use efficiency is similar for situations in which water stress occurs uniformly throughout the growing season, or during the first or second five weeks of development. WUE is greatly reduced when water stress occurs during the last five weeks of development.

FUTURE PLANS: This experiment will be run again during the 1994 growing season with no changes other than planting at an earlier date (early April), similar to that of other canola grown in this area and recommended by Vigil.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

David C. Nielsen
Central Plains Resource Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Precipitation timing and amounts exhibit wide year-to-year variation, producing variations in timing and severity of water stress. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield. The objectives of this experiment were to:

1. Determine water use-yield relationships for selected alternative crops.
2. Quantify water use amounts by growth stage and determine depth of water extraction for selected alternative crops.
3. Quantify development of leaf area and accumulation of above ground biomass for alternative crops.
4. Determine heat unit (growing degree day) requirements for alternative crops.
5. Determine residue production (% cover and mass of residue) and persistence of residue over time for alternative crops.

Objective 5 was not pursued during 1993.

APPROACH: Initial crops tested during the 1993 growing season were canola (Westar), crambe (Meyer), lentils (Indianhead), black turtle beans (Midnight), blue speckled tepary beans, Austrian winter peas, Tinga flat peas, dwarf corn (Cargill 1077), and sunflower (Triumph 546). The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses.

Weekly measurements of soil water content were made with a neutron probe at 0.45, 0.75, 1.05, 1.35, and 1.65 m. Soil water content in the 0-0.30 m layer was determined by Time Domain Reflectometry. Precipitation was measured in the plot area episodically. From these measurements, evapotranspiration was calculated by the water balance method, and rooting depth was estimated from observations of soil water depletion.

A nearby, automated weather station provided necessary environmental data for the calculation of growing degree days and potential evapotranspiration.

FINDINGS:

SEED AND FORAGE YIELDS

Overall, only the dwarf corn showed a strong seed yield response to water use. We aren't sure why there is so much scatter in some of the data (yield vs. ET), but think that some of it is attributable to the difficulty in harvesting some of these small seeded species (canola, crambe, lentils), and perhaps missing the best harvest time for the indeterminate crops like peas and lentils. The forage yields similarly showed a lot of variability, with only the lentils showing a detectable increase in forage yield with increasing water use. The 0 yields for the Tinga flat pea all occurred at the outside edge of the gradient. It appears that these peas need some minimum amount of water to become established and competitive with weeds, and when that minimum amount of water is obtained large amounts of forage material can be produced. The following tables show the ranges in seed yield, forage yield, and water use obtained in 1993.

Table of seed yield and evapotranspiration ranges

	Seed Yield	Evapotranspiration
Canola	1085-2603 lb/a	11.47-19.09 in
Crambe	1334-2002	12.04-18.56
IH Lentils	241-978	16.51-24.23
AW Peas	956-3297	11.71-21.62
BS Tepary Beans	1796-2087	9.92-22.62
Blk Turtle Beans	1687-2972	
Sunflowers	1744-2577	15.71-25.04
Dwarf Corn	1493-4100	12.32-24.47
Tinga Flat Peas	No Seed harvested	

Table of forage yield and evapotranpiration ranges

	Forage Yield	Evapotranspiration
IH Lentils (7/13)	1384-5985	7.51-9.84
IH Lentils (8/13)	3180-6872	--------
AW Peas (7/13)	3537-7439	11.71-21.62
TF Peas (9/03)	0000-9725	16.25-31.51

WATER EXTRACTION PATTERNS

The canola and crambe had similar water extraction patterns, with fairly uniform extraction in the 2nd, 3rd, and 4th depths of about 1.0 to 1.3 in per 30 cm depth. There was some water extraction in the 5th and 6th depths. Lentils were similar, but with slightly more water extraction at each depth. Austrian winter peas and blue speckled tepary beans extracted water similarly to canola and crambe in the 2nd and 3rd depths, but used much less water in the 4th, 5th, and 6th depths. Dwarf corn used the least amount of stored soil water of any of the

crops tested, with only small amounts of water used out of the 4th, 5th and 6th depths. Sunflower used the most amount of stored soil water, and used it uniformly throughout the profile with 1.72 to 1.99 in used per each of the 30 cm depths.

GROWING DEGREE DAYS

For the analysis of GDD we used the formula [(Tmax+Tmin)/2]-Tbase, where temperatures are in C and Tbase were those values used in the model EPIC. Tbase for canola, crambe, Austrian winter peas, Tinga flat peas, and lentils was 1 C; Tbase for sunflowers was 6 C; Tbase for corn was 8 C; Tbase for beans was 10 C.

Cumulative GDD needed to mature the various crops were:

canola	1575
crambe	1746
bst bean	1019
sunflower	1548
dwarf corn	1489

Cumulative GDD for the peas and lentils are not given because we are not sure what they mean, since the crops are indeterminate and we missed to first seed set.

INTERPRETATION: It is still too early to make an interpretation of this data, but it does appear that some of these crops will be suitable as both dryland and irrigated alternative crops.

FUTURE PLANS: We plan to continue this experiment without significant changes in 1994. We will try to make more frequent observations of crop growth stage so that computations of water use by growth stage and GDD to certain growth stages can be computed. If we have sufficient help we will try to start making some of the other measurements regarding leaf area and residue production and persistence.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

David C. Nielsen
Central Plains Resource Management Research Unit

CRIS: 5407-13000-002-00D

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. The objectives of this experiment were to determine:

1. Which cultivar of a particular species is best adapted to this environment.
2. The optimum plant population for dryland production of seed and dry matter of selected alternative crops.

Recommendations can be obtained from other locations for many alternative crop species, but environmental conditions will probably alter the choice of cultivar and optimum seeding rate.

APPROACH: Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review.

During the 1993 growing season three crambe cultivars, two pea cultivars, two dry bean cultivars and one lentil cultivar were evaluated, each at two seeding rates. The two seeding rates were higher and lower than recommended rates from other sources. The various cultivar/seeding rate combinations were planted in a randomized complete block design with three replicatons. Individual plots were 10 by 20 ft.

FINDINGS: Statistical analysis of the yields showed that because of the high variability between reps, there was no significant difference due to population with any of the species, and there was no significant difference in yield of varieties of a given species of crambe or black turtle bean, although the trend was for higher yields at the higher populations with all crops except Belenzian crambe and 906 black turtle bean.

Table of yield ranges

Crambe (seed)	443 to 775 lb/a
Lentil (seed)	1092 to 1407 lb/a
Lentil (dry matter)	2149 to 4758 lb/a
Pea (seed)	548 to 895 lb/a
Pea (dry matter)	5011 to 5182 lb/a
Black turtle bean (seed)	1307 to 1537 lb/a

INTERPRETATION: The crambe yields were quite low, and may be due to a combination of late planting, low rainfall, and poor harvest technique. Virtually no stand of Tinga flat pea established itself at either population. This result seems to confirm observations made in other plots in previous years and this year that unless a critical amount of precipitation (quantity unknown at this time) during the first few weeks of growth, Tinga flat pea cannot become established to successfully compete with weeds. Precipitation during May and June was 54% of normal. Tinga flat pea is extremely slow growing in the early weeks of development. Bean, lentil, and pea yields indicate promise as alternative crops.

FUTURE PLANS: The experiment will be conducted similarly next year with the addition of two populations of blue speckled tepary beans. Plot size will be increased to 20 by 20 ft. More detailed observations of early season growth and development of Tinga flat pea will be made to understand the conditions under which it does not establish and compete well.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE, WATER STRESS, AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

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CRIS: 5407-13000-002-00D

PROBLEM: Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Precipitation timing and amounts exhibit wide variation from year to year in this area, producing variation in timing and severity of water stress. Information is needed regarding water use patterns, rooting depth, evapotranspiration/yield relationships, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains. The specific objectives of this experiment are to quantify the following quantities for alternative crop rotations and compare them with those obtained from conventional wheat-fallow:

1. Water use amounts during vegetative, reproductive and grain-filling growth stages
2. Depth of water extraction
3. Water stress during vegetative, reproductive and grain-filling growth stages
4. Water use-yield relationships
5. Long-term water balance and precipitation storage and use efficiencies
6. Long-term water movement in the soil that could move pesticides and fertilizers into ground water

APPROACH: Seven rotations (see Table 1) are used for intensive measurements of water use and water stress effects on yield. The seven rotations were selected over others because of the hypothesized differences in rooting depth, water extraction ability, water requirement, and sensitivity to water stress. FLEX plots were planted to corn in 1993 (following corn in 1990, grain sorghum in 1991, and spring wheat in 1992). Measurements of soil water content are taken at two locations in each plot at weekly intervals using a neutron probe at depths of 0.45, 0.75, 1.05, 1.35, and 1.65 m. Soil water content in the 0-0.30 m layer is determined by Time Domain Reflectometry. Precipitation is measured adjacent to the plot area episodically. From these measurements, evapotranspiration is calculated by the water balance method, and rooting depth is estimated from observations of soil water depletion.

An infrared thermometer is used to measure canopy or leaf temperatures, and a psychrometer is used to measure wet and dry bulb air temperatures as often as possible during the growing season when clear skies prevail. These measurements are used to calculate the Crop Water Stress Index (CWSI) to quantify water stress.

Leaf area index, crop height, and plant growth stage are measured weekly to quantify water stress effects on plant growth and development. Final grain yields are taken to quantify water stress effects on plant productivity.

FINDINGS: Table 1 shows a summary of the data collected in 1993 in a greatly reduced form, but trends are still evident. Growing season water contents were distinctly different in 1993 than in 1992. Starting soil water in spring for the wheat plots was generally higher in 1993 than in 1992, which resulted in higher leaf area indices, lower water stress, greater water use, and higher yields. Wheat yields following millet were only 26% of wheat following a fallow period. Starting soil water for the corn and safflower plots was lower in 1993 than in 1992 resulting in lower leaf areas, higher water stress, lower water use and lower yields. The corn in the CFW rotation had the highest yield. Sunflower yields were higher in 1993, primarily a result of 55% greater starting soil water compared with 1992. Millet yields between rotations were greatly different, with the higher yield in the MWC rotation. This crop had 2.25 times more soil water at planting due to the effective snow trapping of the previous corn crop residue. The other millet crop was grown on safflower residue, which caught much less snow.

INTERPRETATION: The data collected in 1993 show that the measurements of starting soil water, CWSI, leaf area development, seasonal water use, and yield are all correlated, and that it is important to manage crop residues effectively to capture snow and reduce evaporation. It is becoming more apparent that the millet-wheat-safflower rotation is too water-demanding for this environment.

FUTURE PLANS: Water use, water stress, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made next year. We expect that one more year of data collection will be necessary before the initial publications of this data can be made, since we have only two years of data with the correct overwinter residues influencing starting soil water content. We still have plans to use the data collected in this study to validate the model EPIC and run long-term (20 year) scenarios of production under various rotations using Akron weather records as a means of assessing the viability and potential of various crop rotations for this area.

Table 1. Summary of yield, cumulative evapotranspiration (CET), starting spring soil water content, maximum leaf area index (LAI), average seasonal Crop Water Stress Index (CWSI) for selected alternative crop rotations, 1993.

Crop	Rotation	Yield (kg/ha)	CET (cm)	Date of Starting Soil Water	Starting Soil Water (cm/120cm)	Max LAI	Average CWSI
Wheat	WF (NT)	3807	36.4	24 MAR 93	16.8	2.97	0.42
Wheat	WF (CT)	2539	35.0	24 MAR 93	14.2	2.66	0.51
Wheat	WCF (NT)	3115	34.2	24 MAR 93	14.5	3.17	0.47
Wheat	WCM (NT)	927	23.3	24 MAR 93	11.1	1.65	0.61
Wheat	WSAFM (RT)	736	20.2	24 MAR 93	11.8	1.89	0.63
Corn	FLEX (NT)	947	31.3	13 MAY 93	9.3	1.48	0.47
Corn	CFW (NT)	2438	34.1	13 MAY 93	13.0	1.45	0.40
Corn	CMW (NT)	1382	30.9	13 MAY 93	8.8	1.54	0.49
Corn	CSUN (RT)	1585	28.0	13 MAY 93	7.7	1.00	0.41
Millet	MWC (RT)	2474	27.0	22 JUN 93	19.5	1.77	0.44
Millet	MWSAF (RT)	1291	22.0	22 JUN 93	8.8	1.80	0.58
Safflower	SAFMW (RT)	484	29.2	24 MAR 93	6.0	1.16	0.48
Sunflower	SUNC (RT)	1913	40.1	08 JUN 93	18.0	2.67	0.23

WF=wheat-fallow
WCF=wheat-corn-fallow
WCM=wheat-corn-millet
WSAFM=wheat-safflower-millet
CFW=corn-fallow-wheat
CMW=corn-millet-wheat
CSUN=corn-sunflower
MWC=millet-wheat-corn
MWSAF=millet-wheat-safflower
SAFMW=safflower-millet-wheat
NT=no till
CT=conventional till
RT=reduced till

WIND VELOCITY, SNOW, AND SOIL WATER MEASUREMENTS IN SUNFLOWER RESIDUES OF VARYING HEIGHT AND DENSITY

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CRIS: 5407-12130-003-00D

PROBLEM: Sunflower is an economically viable crop for dryland crop rotations in the central Great Plains. However, concerns about wind erosion during the summer fallow period following sunflower harvest arise due to the assumed low residue amounts left by sunflower after harvest, resulting in inadequate protection for the soil surface against wind erosion.

Wind erosion estimates within sunflower residues in the west-central Great Plains are questionable with existing data and estimation methods. Research done by ARS scientists while developing a wind erosion model have discovered calculated soil losses by wind from the traditional Wind Erosion Equation (WEQ) may significantly underestimate soil losses in the western portion of the Central Great Plains. Quantitative wind velocity data is specifically lacking for sunflower residues in this region of the U.S. More accurate estimates of soil loss by wind will be possible using the new wind erosion model if wind velocity data for sunflower residues are obtained. The ability of sunflower residues of varying height and stalk densities to trap snow needs to be quantified, as well as the resultant changes in over-winter and spring soil water content to assess the production potential of dryland sunflowers grown in crop rotations in this region. Development of quantitative data regarding actual reductions in wind velocity and increases in snow catch and soil water due to managed sunflower stubble will encourage farmers to diversify cropping systems to include sunflower.

The specific objectives of this study are:

1. Measure wind velocities and residue amounts within sunflower residues at various heights above the soil surface for:
   - A. two standing, non-tilled, sunflower stalk heights,
   - B. three plant populations, and
   - C. sunflower residue conditions after various tillage operations, including sweep-plowing, disking, and no tillage, with and without standing wheat stubble from the previous winter wheat crop.

2. Measure snow depth differences that occur in response to the residue management treatments outlined above.

3. Measure changes in soil water content that occur over winter and spring in response to the residue management treatments outlined above.

APPROACH: Plots with approximate dimensions of 45 m by 45 m (150' by 150') were established to minimize border effects on wind velocity and snow catch, and to allow measurement of wind velocity from all wind directions. Oil-seed sunflowers were planted in

0.76 m (30") row spacing at 32100, 37100, and 61800 plants/hectare (13000, 15000, 25000 plants/acre). At harvest, plants were cut to leave standing stalk heights of approximately 0.30 and 0.60 m (12" and 24"). One set of plots will have stalks flattened with a roller after harvest. Wind velocities were measured with micro-response, cup anemometers at 2 m (6.5') above the soil surface and at 3 heights within the standing stalk residue to obtain wind profile data. Wind direction was measured at 2 m (6.5') with a wind vane. Stalk heights, densities, diameters, residue mass and percent cover were measured after harvest. Soil water content is measured after harvest and periodically throughout the winter and spring using neutron scattering and time domain reflectometry techniques. Snow depth is measured following each snowfall and/or period of high wind with potential for drifting.

FINDINGS: Residues from two plots planted during the 1992 growing season had sufficient amounts of residue to allow measurements in the spring of 1993. These plots had stalk populations of 28,785 and 18,889 stalks/acre, and were cut to 63 cm. The wind velocity profile data are currently being analyzed. The 1993 plots were planted in the spring on property owned by Roger Ashley. Unfortunately, these plots were located in an area of deficient soil water, and limited growing season precipitation resulted in poor stands. Nevertheless, we have installed the anemometers and obtained wind velocity profiles at two stalk heights and three populations, and the data are currently being analyzed. Two sites of better sunflower stalk stands were located on a bulk planting of sunflower on the CGPRS, and wind velocity profiles will be obtained from these plots in the spring of 1994. During the 1992-1993 winter period, sunflower stalks cut to 73 cm were much more effective at trapping snow than stalks laid flat after harvest, resulting in more than 2.5 times more stored soil water in the spring.

INTERPRETATION: Standing sunflower stalks are effective at reducing wind speed at the soil surface, and increasing snow catch, thereby reducing the potential for wind erosion and increasing precipitation storage efficiency.

FUTURE PLANS: We plan to conduct this study in its entirety on another set of plots planted on the CGPRS in 1994.

NITROGEN RESPONSE OF SPRING AND WINTER CANOLA

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CRIS: 5407-12130-003-00D

PROBLEM: Canola is a potential oilseed crop for the central Great Plains. Much of the basic agronomic knowledge required to make canola a successful option in the Central Great Plains is unknown. Management information such as variety selection, nutrient requirements, heat unit requirements, and planting date have not been established for canola in our region.

APPROACH: The N response and yield potential of 9 spring varieties and 3 winter varieties are being evaluated in a split-block designed field experiment with varieties as main plots and nitrogen (N) rates as subplots. Individual experimental units are 30 (9.144m) by 40 (15.24m) ft. The experiment is established under two different previous crop-management histories: wheat stubble or fallow ground previously planted to dryland corn.

In August prior to winter canola establishment all plots are top dressed with 0, 40, or 80 lb N as ammonium-nitrate. Winter varieties are planted mid to late August. Spring varieties were planted when surface soil temperatures reached an average temperature of 4°C (39.2°F) (the last week of March). All varieties are planted 1 inch deep, at a seeding rate of 900,000 seeds/acre, using a Tye no-till-disk drill. For weed control treflan is applied (1-1.5 lb a.i.) preplant with a granule applicator attached to a sweep plow with mulch treaders.

FINDINGS: Alto and Westar performed the best in both fallow and stubble (Table 1). Oil yields tend to fallow grain yields with Alto and Westar as the best performers. On average a yield advantage of about 500-600 lbs of grain was measured in the fallow verses stubble plots. Pre-plant soil water contents were only 0.3 inches greater in the fallow plots so yield differences are attributed to greater weed pressure in the stubble plots as compared with fallow. These data suggest the N requirement is between 6 and 11 lb of N per 100 lb of grain for the varieties Westar and Alto. Hail damage precluded an accurate measure of plots yields in 1993. However, small grab-bag samples indicated that canola yields were 200 to 400 lbs less in 1993.
We have had little success with winter varieties. In 1992 we experienced 100% winter kill. In 1993 we observed 100% winter kill in stubble. In fallow plots in 1993 we observed 100% winter kill in reps 1 and 4. In reps 2 and 3 we observed only 10-15 % winter kill.

INTERPRETATION: From this data set we anticipate that canola has potential in our region. On average 3 inches of rain is received in May and 2.7 inches in June. In 1992 we received 3 inches in May and 3.9 inches in June which appears to be what canola needs for good seed yield. In 1993 only 1 inch of rain was received in May and 1.7 inches in June. Hail eliminated a fair measure of yield potential in 1993. However, estimated yields were much less.

FUTURE PLANS: We would like to continue the experiment for a total of at least 3 years as a measure of environmental variability.

Table 1. Spring canola as affected by variety N rate in fallow and stubble plots in 1992.

		Fallow				Stubble			
N rate lb/acre	Variety	grain yield	oil yield	N uptake	Total Biomass	grain yield	oil yield	N Uptake	Total biomass
		lb/acre				lb/acre			
0	Alto	767	339	71	4230	615	273	63	3241
0	Global	479	206	50	3315	339	147	55	3420
0	Parkland	321	138	60	3368	461	202	59	3655
0	Tobin	387	159	50	3306	410	169	53	3422
0	Westar	773	337	53	4053	445	196	32	1967
40	Alto	1108	484	95	4743	776	336	93	4832
40	Global	815	341	100	5131	493	213	85	4578
40	Parkland	701	301	79	4263	462	198	46	3346
40	Tobin	664	267	81	3955	647	263	63	3795
40	Westar	1195	520	97	5614	680	294	75	3931
80	Alto	1202	505	104	5332	775	321	78	3651
80	Global	887	355	111	4675	539	219	102	4659
80	Parkland	670	288	96	4433	485	209	55	3108
80	Tobin	691	273	113	4928	753	301	83	4767
80	Westar	1408	585	82	4458	904	378	55	2790

CARBON AND NITROGEN MINERALIZATION FROM DECOMPOSING CROP RESIDUES

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PROBLEM: The amount of NO_3-N entering groundwater supplies is a national concern. The NO_3-N entering ground water comes from N mineralized from native soil organic matter, organic amendments, crop residues, and from fertilizer applied in excess of the amount required for sustainable crop yields. The excess NO_3-N (particularly the mineralized NO_3-N) is not always in synchronization with maximum crop uptake and is therefore potentially leachable. Most laboratories recommending N fertilizer either ignore or simply guess at the amount of N mineralized from organic sources. The problem lies in the complexity of N turnover which is affected by variable soil, and residue characteristics, and variable soil environment from year to year. Simulation models which mimic the processes of organic N turnover, crop N uptake, and soil water movement, allow for the integration of variable residue, soil, and environmental factors and can be used to predict these processes.

APPROACH: The objective of these experiments are to evaluate and improve existing simulation models to accurately predict: (i) seasonal N dynamics under field conditions. (ii) available N in synchronization with crop uptake (iii) N available for leaching. The MINIMO subroutine (The mineralization immobilization subroutine for the EPIC, and CERES-maize models) has been tested for its ability to mimic the mineralization of N from ^{15}N-labeled crop residues under field conditions. In those studies the simulation model over predicted the amounts of N mineralized. Rate constants for decomposition of plant materials in MINIMO have been derived from laboratory studies with finely ground plant materials mixed with soil. Crop residues decomposing under field conditions are usually not finely ground. The over prediction may partially be related to rate constants in MINIMO. Laboratory investigations of N mineralized from the surface soil of a typical Platte Valley soil mixed with corn residues of variable N concentration and 5 particle sizes has been under way since June of 1990. Residue soil mixtures are incubated and periodically leached with 0.01 M $CaCl_2$ using a modified Stanford and Smith approach. The collected data will be used to modify the MINIMO model to take into account crop residue condition in the field (i.e. stalks chopped vs disked, or left on the surface).

FINDINGS: The amount of N mineralized (as measured by accumulated inorganic N) decreased with decreasing residue particle size for corn leaf residues (C/N ratio of 25). This relationship between leaf particle size and the amount of inorganic N accumulated was consistent for all 4 particle sizes. For leaf particles ground to less than 2 mm, only 25% of the residue N was

recovered 174 days after residue incorporation. For larger leaf particles 40 mm long by 10 mm wide up to 75% of the residue N was recovered 174 days after residue incorporation. For corn stalk particles (C/N ratios of 65 to 70) we measured net immobilization during the entire 174 day incubation. Less immobilization was measured for the largest corn stalk particle sizes. A follow up study was conducted during the summer of 1993 to look at CO_2 accumulation during decomposition in closed containers and denitrification. This study shows greater denitrification and CO_2 accumulation with decreasing particle size from closed containers.

INTERPRETATION: Even though the actual amount of accumulated inorganic N was less with the smaller particle sizes we measured greater CO_2 accumulation in tubes with crop residues of the smaller particle sizes. It is reasonable that the greater surface area with the smaller particles would provide a greater opportunity for microbial attack. We suspect that much of the N not accounted for during this decomposition may be either immobilized as microbial N or lost through denitrification. Denitrification is supposed to be minimal at water filled porosities less than 60%. This experiment was conducted at water filled porosities of 55% or less. However it is possible that the soil micro-environment around individual particles may go anaerobic if decomposition proceeds rapidly enough. This would void the 60% water filled porosity rule of thumb for the decomposition of crop residues of sufficiently small size.

The wide C/N ratio of the corn stalk residue resulted in net immobilization for 174 days at optimum moisture and near optimum temperature. From other research we have conducted we know that decomposition under field conditions in the midwest proceeds approximately 30 to 50% slower than under laboratory conditions. Under field conditions a net immobilization of corn stalk residues may be for a year or more.

FUTURE PLANS: Follow up research may be conducted if needed to quantify the amount of denitrification in this system. The collected data needs to be further analyzed before determining what additional research will be needed.

AN EVALUATION OF NITRIFICATION INHIBITORS AND PRECISION PLACEMENT OF LARGE UREA PELLETS FOR IRRIGATED CORN

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PROBLEM: Efficient use of fertilizer N sustains crop yields, reduces producer expenditures for fertilizer, and minimizes environmental contamination. Recent research with irrigated corn in Colorado and wheat in North Dakota has shown significantly improved N fertilizer uptake when the nitrification inhibitors CaC_2, and DCD (dicyandiamide) are mixed with urea. In Kansas with cool season grasses, large urea granules significantly increased N uptake when compared with conventional urea fertilizer. Research done in Texas where fertilizer N was placed only in the non-irrigated rows of irrigated crops showed greater N recovery and therefore less potential for N leaching losses than conventionally placed fertilizer N. In this study a combination of these products and placement strategies are being tested to maximize the fertilizer use efficiency of irrigated corn.

APPROACH: The objective of this study is to determine the best combination of inhibitor and fertilizer placement in the non-irrigated row for irrigated corn to increase N use efficiency and reduce fertilizer N lost to leaching. The study was initiated the spring of 1990 on a Hall silt loam near Shelton, Nebraska at the MSEA site. Large 1.7 g urea pellets were placed 10 cm deep and 10 cm away from rows of V1 stage corn (1990) and V3 stage corn (1991) at 20 cm intervals along the row. Nine treatment combinations of large urea pellets with or without two nitrification inhibitors (CaC_2, or DCD) were applied at N rates of 40, 80, or 120 kg N/ha. Conventionally banded urea and a check with no fertilizer applied were also included in the experiment. Microplots within larger field plots were established at all treatment combinations for the 40 and 120 kg N/ha rates. These received ^{15}N labeled urea to allow for estimation of fertilizer N recovery and plant N derived from fertilizer. Inorganic N levels in the zone of fertilizer application were monitored 7, 32, 43, and 96 days after fertilizer application. Chlorophyll meter readings, leaf punch N, total plant N, and total plant dry weights were measured 30, 34, 45, 59, 76, and 119 days after emergence.

FINDINGS: Soil NO_3-N levels were significantly less in the zone of fertilizer application of inhibitor treated plots one week after fertilizer application (during early vegetative growth) than in plots without inhibitors. At 32 days after N application both inhibitors maintained significantly higher ammonium N than plots without inhibitors. At 43 days the effect of the CaC_2 inhibitor

on soil ammonium-N was not measurable in the zone of fertilizer application. At 43 days DCD was still maintaining approximately 65% of the ammonium N for either CaC_2 treated plots or plots without inhibitor. The percentage of plant N derived from fertilizer (PNDF) and the percent of fertilizer N recovered (PFNR) by the crop were significantly higher for the banded urea treatments at the V7 stage (30 days after emergence). At 76 days after emergence significantly greater PNDF and PFNR were found in plants harvested in the nitrification inhibitor treatments as compared to the banded urea and large urea pellet treatments. This information suggests that the low amounts of NO_3-N found early in the inhibitor treated fertilized plots is correlated to the low amounts of N uptake also found in those plots early in the season. A greater accumulation of N found in the inhibitor treated plots late in the season follows the higher amounts of NO_3-N found later in the Inhibitor treated plots. These data demonstrate the importance of timing the release of inorganic N (particularly NO_3-N) by the inhibitor treated fertilizer to the period of maximum crop N uptake.

Data collected in 1991 showed similar relationships with respect to N uptake and nitrification inhibition. In 1991 we measured an 8 bushel increase in plots fertilized with the large urea tablets as compared with plots fertilized with conventionally banded urea, and/or inhibitor treated fertilized plots. In 1991 fertilization was done later at V3 verses V1 in 1990. It is possible that the V3 stage was just late enough to reduce inorganic N levels in the inhibitor treated soils to have missed the maximum N uptake period of the crop. Whereas the larger tablets may have dissolved, hydrolysed and nitrified just slow enough to have resulted in greater amounts of inorganic N as compared to the other treatments during the high N demand period of the crop.

INTERPRETATION: The DCD which was intimately incorporated with the urea maintained fertilizer ammonium N in the ammonium form for a longer period of time than CaC_2. The CaC_2 was not as intimately mixed with the urea as the DCD and only placed with the urea in the fertilized Zone. The greater encapsulation found with the DCD may partially explain the increased time of effectiveness measured with the DCD plots. Preliminary experiments in the laboratory with the wax coated CaC_2, indicated that we could expect a total conversion of the CaC_2, to acetylene (acetylene is the actual active agent that inhibits the conversion of ammonium to nitrate) in about 10 days.

Since we haven't yet analyzed all of the 1992 data we can't indicate which combination of fertilizer and inhibitor is better at improving fertilizer use efficiency. It is possible that the DCD treatments inhibit the conversion of ammonium to nitrate for longer than required for maximum fertilizer uptake. From the literature we know that rapidly growing corn plants that are past the seedling stage prefer nitrate-N over ammonium-N. We also know that high concentrations of ammonium are toxic to plant roots. It is possible that the duration of delay in the conversion of ammonium to nitrate with DCD may be too long and may actually decrease the total fertilizer N recovered.

FUTURE PLANS: After analyzing the 1992 data we will decide what further study should be conducted to support this research. We hope to have all of the ^{15}N-labeled plant material and soil inorganic N data analyzed for the 1992 season by the end of March of 1994.

INVESTIGATION OF BASE TEMPERATURE AND PLANTING DEPTHS OF SPRING CANOLA AND SAFFLOWER

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CRIS: 5407-12130-003-00D

PROBLEM: Canola and safflower have recently been identified as potential alternative crops for the Central Great Plains. Very little information exists in the literature concerning the heat unit requirements for their growth, development, and production. An understanding of the match between their physiological heat unit requirements and the historical record of a given crop producing region will aid in the successful match and development of appropriate varieties and management practices for a given region. Quantification of the heat unit requirement for germination and physiological development of canola and safflower can be used to help guide producers, researchers and extension personal in making informed management decisions with respect to optimal spring planting dates, time of expected seedling emergence, time required for the onset of flowering, and the onset and duration of the grain filling period. The heat unit quantification of canola and safflower can potentially aid in the selection of the proper variety for a given location in the Central Great Plains and aid plant breeders in the selection and development of appropriate genetic material for a given location. The objectives of this study are to develop models to predict seedling emergence characteristics as a function of soil temperature and planting depth, and to provide data for the development of heat unit requirements for the germination of these crops. Models will be used as an aid to guide producers in early season management of these crops.

APPROACH: In this first of a series of potential investigations we examined the amount and rate of germination of two spring canola varieties (Tobin and Global) and one safflower variety (S-208) as affected by planting depth and temperature. Individual 500 ml clear plastic pots were marked and filled with soil at a wet bulk density of 1.0 with either Platner silt loam or Weld silt loam. The experiment was conducted at constant soil water contents of either 16 or 20 percent gravimetric water content. Individual pots marked at various depths were partially filled with moist soil to a specified mark on each pot. Twenty seeds were placed at equidistant spacings on the surface of the soil and then covered with soil to the appropriate depth. Seeds were planted at 5 different planting depths of 1, 2, 2.5, 3, or 4 cm (one depth and variety per plastic pot). A complete replication of one soil type at one soil water content consisted of 40 pots (2 varieties, by 5 planting depths, by 4 temperatures). The appropriate individual pots were then placed into separate constant temperature incubators at 4, 8, 12, and 16°C (39.2, 46.4, 53.6 and 60.8°F) which corresponds to early spring temperatures in the Central Great Plains during the months of March and April. The complete experiment was replicated 2 times. The number of seeds germinated in each pot were counted on a daily basis initially and then twice daily during the rapid germination phase at 16 and 12°C. Germination measurements and accumulated heat units were determined for a 55 day period from December 17, 1991 to February 12, 1992.

We repeated the experiment for the same varieties Global and Tobin at 0, 2, 4, and 16°C. Three additional varieties were included in this second experiment these were Alto, Crystal, and Glacier.

FINDINGS: From these two experiments we found that the base temperature for canola is very near 0°C (32°F). Essentially no emergence was observed at 0°C. We also found that regardless of the constant temperature regime imposed that emergence begins at between 1500 and 1800 growing degree hours (GDH) for the spring varieties Global, Alto and Tobin at the 1 cm planting depth. For the winter varieties we found that 1800 to 2700 GDH were required to emerge. Germination of canola was essentially complete for all depths 12 days after planting at 16°C, 22 days after planting at 12°C, 30 days after planting at 8°C, and 47 days after planting at 4°C. We measured up to 95% germination at the shallower depths at 16°C by day 12 with an average of near 68%, at 12°C we measured up to 90% germination at the shallower depths with an average near 65% by day 22. At 8°C we measured up to 70% germination with an average of 50% on day 30. At 4°C we measured up to 60% germination with an average of 20% by day 50.

INTERPRETATION: Preliminary analysis indicates we might expect severe reductions in stand when canola is planted at soil temperatures that will be sustained much below 8°C. This preliminary analysis suggest that spring canolas should be planted not much earlier than the last week of March and that increased seeding rates may help to off set the expected loss in stand if planted earlier when temperatures are cooler. Preliminary observations of safflower suggest similar trends.

FUTURE PLANS: We have found that canola and safflower will germinate at temperatures of 4°C. The study is complete and will be put into manuscript form within the next year.

WHEAT RESIDUE DECOMPOSITION AS AFFECTED BY HERBICIDE AND UAN APPLICATION UNDER FIELD CONDITIONS

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Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00D

PROBLEM: The amount and type of crop residues left on the soil surface after harvest affects soil erosion. For farmers to be in conservation compliance (1985-1990 farm bill) they must have, in accordance with their conservation plan, a specified amount of crop residue cover at planting time. Unfortunately, crop residues decompose after harvest and become less resilient and durable during the non-cropped part of the season. These partially decomposed crop residues can then be wind blown from a field and lost in the same manner as soil. Management schemes that maximize crop residue durability should maintain greater residue cover during the non-cropped period, minimizing both soil and residue loss. These schemes should insure that adequate residue cover is present at planting time when compliance-residue-cover is measured. Much information is available regarding the affects of soil water content and soil temperature on crop-residue decomposition rates. Likewise, there is much information regarding the effect of crop residue N and soil N concentrations on residue degradation. However, minimal quantitative information exists on the durability and resiliency of standing crop residues as affected by the applications of herbicide and N fertilizer. The objectives of this research are: 1) To quantify how the durability and resiliency of standing crop residues are affected by applications of N fertilizer, and herbicides under field conditions. 2) To make this information available to farmers, SCS, and to the cooperative extension service through field days, a conservation tillage newsletter, popular news articles, and fliers.

APPROACH: Just after wheat harvest (August of 1993) 45 by 16 foot field plots were established with the following treatments where all rates are active ingredient/acre: 1) 0.5 lb Command + 0.5 lb Atrazine applied mid-August. 2) 0.5 lb Glyphosate + 0.25 lb Dicamba (Banvel) applications as needed. 3) 0.5 lb Paraquat + 1.0 lb Atrazine applied mid-August. 4) 0.5 lb Paraquat + 0.25 lb 2,4 D as needed. 5) no treatment, hand weeded (plastic spread over top of hand weeded area). 0.5 lb Command + 0.5 lb Atrazine. 6) tillage, no herbicide 2-3 times as needed (sweep plow with mulch treader). Superimposed onto these treatments are three N regimes: no N applied, 30lbs N as UAN, and 60 lbs N as UAN. All plots are replicated 3 times and arranged in a randomized complete block design. The following measurements are being taken. 1) Photo-documentation of plots was done after plots were established, after herbicide application, and then periodically as needed to document differences or lack of differences due to treatments. 2) The number of standing wheat stems is counted in select areas of each plot once a month during the no-snow months (depending on snow depth). Measurements will continue until planting of the next wheat crop. 3) Periodically, the weights of wheat residues

lying on the soil surface between rows of standing stems inside fiberglass mesh bags will be collected weighed, dried and reweighed. To determine the difference between wheat residue decomposition and wheat residue lost by wind erosion, hail screen will be placed on half of the strip to minimize wind blown additions or losses of wheat residues. Hail screen covered wheat will be gathered and weighed separately from uncovered wheat. 4) Periodically (at least 3 times) residue samples will be taken from each plot to determine residue carbon (C), nitrogen (N), fiber, and ash contents to characterize residue durability as affected by treatments. Precipitation; maximum and minimum soil temperatures at 5 cm depth, air temperatures at 1 m height on a weekly basis and at residue measuring times. Initial and final soil water contents at 0-10 cm, 10-30 cm depths. Surface soil (top 10cm) and residue water contents at 7:40 am and at 2:00 pm on a daily basis for 25 days after harvest. This data will be used to calibrate a model to predict soil and crop residue water contents on a daily basis for a crop residue decomposition model.

RESEARCH TIMETABLE:

	MONTHS											
Years	1	2	3	4	5	6	7	8	9	10	11	12
1993							H1 E1	M1	M1	M1	M1	M1
1994	M1	M1	M1	M1	M1	M1	H2 E2 M1	M1 M2	P1 M2	M2	M2	M2
1995	M2	M2	M2	M2	M2	M2	H3 E3 M2	M2 M3	P2 M3	M3	M3	M3
1996	M3	M3	M3	M3	M3	M3	M3	M3	P3	A	A	A
1997	A	A	A	A	A	A						

P = planting 1 = 1st year of the study
H = harvest 2 = 2nd year of the study
M = measurements being made 3 = 3rd year of the study
A = final analysis
E = experimental site establishment

FINDINGS: The study has been established since August of 1993. No large treatment differences are observed at this time. As of January 12, 1994 we have lost about 8-12 % of the standing stems originally counted in August of 1993. Laboratory analysis of litter bags placed in the field plots in August of 1993 show less than a 10% loss in residue weight at this time.

INTERPRETATION: Since only preliminary data has been collected at this time no interpretation will be made. A preliminary report will be prepared before the end of the first season of measurements for field days in June of 1994. Annual field day reports will be prepared June of 1995, and June of 1996.

FUTURE PLANS: The experiment will be continued with standing stem counts and litter bag analysis to be taken through out the spring of 1994. We hope to continue this experiment for a total of at least 2 years. We will evaluate as the experiment progressses if further study is needed.

ECONOMIC LOSS OF RESISTANT AND SUSCEPTIBLE WINTER WHEAT TO THE RUSSIAN WHEAT APHID (*DIURAPHIS NOXIA*) MORDVILKO

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PROBLEM: To define the economic injury level of a newly developed resistant variety of winter wheat (RWAE1) and compare it with a susceptible variety (TAM 107). This experiment was a field comparison of the growth and economic yield of RWAE1 with a standard variety (TAM 107). The new resistant variety was developed by Jim Quick, C.S.U. Agronomy.

APPROACH: Two strips of each genotype, eight meters wide, and ninety two meters long were planted on the Central Great Plains Research Station on 18 September 1992. The following spring (21 April 1993), when the wheat reached Zadocks 25-26, forty eight random one linear row lengths were marked off for artificial infesting in each genotype. A bazooka was calibrated with Russian wheat aphids in cream of wheat. For the forty eight rows that were infested in each genotype, twenty four were used for sampling while the remaining twenty four were used for yield. All were infested with 0, 100, 300, 500, 700, and 900 nymphal aphids per row meter with four replications for each infestation level. Sampling consisted of removing .3 meter of row on 10 May (Zadocks 45), 28 May (Zadocks 61) and 6 June (Zadocks 72). The plant material was placed in a Burlese funnel for 24 hr. The number of aphids were counted under magnification. Cumulative aphid days were calculated according to Ruppel (1983).

Yield data for the remaining paired row meter at differing infestation levels were collected on 20 July 1993. The number of spikes per meter were counted prior to clipping and placing in paper grocery bags. The spikes were run through a threshing machine and a seed cleaner before weighing. The total number of seeds per meter, and 1,000 seed count weight were obtained. Analyses of variance were run on the yield variables prior to mean separation using SNK at $P > 0.05$ (SAS Institute ver. 6.04). Linear regression analysis was conducted using cumulative aphid days versus 1,000 seed weight and the dollar loss extrapolated to a per acre basis.

FINDINGS: The 1,000 seed weight was the less variable yield component within genotypes. The RWAE1 weights were consistent across all infestation levels. The TAM separated significantly between different infestation levels. It is interesting to note that the average 1,000 seed weights were almost the same even though the means for TAM ranged from 35.1 to 25.1 g. This 1,000 seed weight data indicates that TAM has the potential for a heavier kernel weight, but under increasing aphid pressure that potential diminishes. The characteristics for the RWAE1 kernel are that it is genotypiclly smaller than TAM, but does not decrease to the degree TAM does under heavier Russian wheat aphid pressure.

The dollar loss per row meter was extrapolated to an acre and compared with cumulative aphid days for both genotypes. The data were highly variable, however some observations can be made. The higher infestation rates for TAM accumulated over 110,000 aphid days. The highest for RWAE1 was under 70,000. This indicates that the reproductive potential for the Russian wheat aphid is much higher on TAM 107 compared with RWAE1. The slope of the

TAM regression curve is greater (.415) compared with RWAE1 (.334). The dollar loss for example at 42,000 cumulative aphid days for TAM is $28.00 compared with $18.00 for RWAE1.

INTERPRETATION: The genotype RWAE1 developed by Dr. Jim Quick, C.S.U. wheat breeder, shows promising potential for dryland wheat in the northeastern plains of Colorado.

FUTURE PLANS: This experiment will be conducted one more year at several locations to further determine the economic benefits of planting a resistant variety.

EFFECT OF ICE NUCLEATING *PSEUDOMONAS SYRINGAE* ON THE SUPERCOOLING POINTS OF THE RUSSIAN WHEAT APHID *DIURAPHIS NOXIA* (MORDVILKO)

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PROBLEM: The overwintering ability of the Russian Wheat aphid (*Diuraphis noxia*) Mordvilko (RWA) has been studied in Colorado since it was found here in 1986. It has shown to have approximately a 50% probability of surviving the winter on the northeast plains of Colorado, depending upon winter environmental conditions. The RWA is freeze intolerant, supercools to <-26^{0}C, and is prone to pre-freeze mortality (mortality prior to -26^{0}C). There are no physiological adjustments (acclimation) made by the RWA to survive cold temperatures. This is shown by the fact that the supercooling point (SCP) is constant over seasons for both greenhouse and field collected RWA, and that assays for changes in cryoprotectants (glycerol, mannitol, trehalose, sorbitol, glucose, and others) do not change on a seasonal basis for greenhouse and field collected test aphids. The RWA has proven to be the most important, economically threatening insect pest of small grains in the Great Plains Area of the United States. If this crop pest successfully overwinters, the damage from early spring infestations will be greater than later migratory movement of aphids from the south. The purpose of this study was to determine if exposing the RWA to *P. syringae* would significantly decrease its supercooling capacity, thus making it more susceptible to winter temperatures. If laboratory exposures proved to be effective, further field work could be conducted in efforts to develop a safe biological method for controlling RWA and perhaps other injurious insect pests.

APPROACH: A colony of RWA were maintained through the winter 1992-1993 on potted 'TAM 107' winter wheat in the greenhouse. The initial aphids came from a natural infestation of winter wheat from the fall 1992.

Individual RWA (apterous, fourth instar) were carefully placed on the surface of a 24 gauge copper constant thermocouple with a camel hair brush and secured with a thin layer of petroleum jelly. The thermocouple was then placed inside a Pyrex^R test tube (1.5cm x 15cm) so that the aphid and thermocouple moved up or down the test tube with ease. This test tube was placed inside a larger test tube (3cm x 16cm) to stabilize the temperature differential. Both test tubes were held partially submerged in a dry ice, 95% ethanol bath where the temperature stayed between -60 and -70 ^{0}C. The temperature was dropped slowly (2^{0}C/minute) by moving the thermocouple further down into the smaller test tube. The thermocouple was attached to a 21x micrologger (Campbell Scientific, Logan Utah) that was programmed to display and record the temperature every 0.20 seconds. The temperature readings were then transferred to a DOS personal computer via a cassette recorder where they could be manipulated in a spreadsheet program. The data were plotted to show the lowest body temperature (SCP) prior to the release of latent heat of energy. Figure #1 shows a graphical representation of a SCP for a field collected fourth instar RWA.

Freeze dried, pelleted *P. syringae* were mixed with distilled water at 25, 50, 75, and 100 mg/ml (mg bacteria/ml water). The exterior of a single aphid was exposed to the suspensions by bursting one time with a mist bottle. A control group were treated with distilled water only. The preparation time from exposure to dropping the temperature was within five minutes.

The same concentrations of *P. syringae* were mixed in a 10% sucrose solution and artificially fed to aphids 5 hr before determination of SCP's. Aphids were fed the solutions by placing small amounts in the lid of a 1 ml plastic centrifuge vial, and covering it with a tightly stretched piece of parafilm. Aphids were enclosed in the vials, and allowed to feed through the parafilm. Only aphids that were actively feeding (had their stylets inserted through the parafilm) were used for SCP's. A control group that were artificially fed 10% sucrose for the same amount of time were also included. Approximately 16 replications (SCP's) of any treatment were conducted depending upon the availability of dry ice.

FINDINGS: Supercooling points of the RWA that were artificially fed *P. syringae* in 10% sucrose or topically exposed to *P. syringae* in water were increased.
The control group misted with distilled water increased from 7 to 8^{0}C while the ingested control increased 3 to 4^{0}C above previously reported SCP's of RWA. This increase must be due to distilled water in contact with the cuticle or hemocoel. Even though the water is distilled, it must contain some ice nucleating material of its own. A linear dose-response of raising the SCP with an increase *P. syringae* suspensions did not occur. In fact, 50 mg/ml had lower SCP's than 25, 75 or 100 mg/ml. In addition, the higher the amount of *P. syringae* in water solution the greater the standard errors. Although the standard errors for ingested treatments are high, they are consistently lower than the corresponding concentrations for misted treatments. These data indicate that ingestion is the more effective exposure for elevating the superooling point.

INTERPRETATION: These preliminary findings indicate that *P. syringae* has potential for use as a biological insecticide in the control of the Russian wheat aphid and other aphid species as well.

FUTURE PLANS: This laboratory work merits further research in the field to investigate the possibility of using *P. syringae* as a biological control for RWA as well as other arthropod pest of small grains.

THE OVERWINTERING BIOLOGY OF *DIURAPHIS NOXIA* (Mordvilko) ON THE NORTHEASTERN PLAINS OF COLORADO

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PROBLEM: If the Russian wheat aphid successfully overwinters, the damage an economic loss can be devastating. What type of winter conditions are responsible for causing 100% mortality in an overwintering Russian wheat aphid population in winter wheat ?

APPROACH: The overwintering biology of the Russian wheat Aphid (*Diuraphis noxia*) Mordvilko was researched in the field and in the laboratory starting the winter of 1988, and continuing to the spring of 1991. The major effort of the research was to determine what type of winter environmental conditions are responsible for 100% mortality in an overwintering population of Russian wheat aphids infesting winter wheat. Environmental data (1988-1991) were used to develop statistical models that explain how environmental factors interact with one another. Two different methods of accumulating subzero temperatures were the basis of independent variables used in developing the models. The field studies involved artificially infesting c.v. 'Tam 107' plants in mid October and periodically sampling them through the winter. Sampling involved removing .3 m linear drill row of wheat plants that had been infested with 30 nymphal Russian wheat aphids for the winters of 1989, 1990, and 1991. Environmental parameters measured were soil surface temperature, (hourly averages for every day starting in October and continuing until the first of April), soil moisture, snowfall depth, number of days with snowcover, and solar radiation. An accumulative freeze index was developed to determine the effect of accumulated long term exposure to sub zero temperatures. Russian wheat aphid numbers were regressed against the accumulative freeze hours.

FINDINGS: The data collected over the 4 winters was useful from the standpoint that weather varied greatly in temperature and snowfall. The models explained that short acute drops in temperature (-30 C) without snowcover could cause 100% mortality. Snowcover depth and duration could be either beneficial or detrimental to an overwintering population of Russian wheat aphids. Greater than 5cm of snow would insulate the aphids from extreme drops in temperature. Long durations of high amounts (>10cm) of snow eventually cause high mortality due to the wet environment. Other factors like solar radiation and soil moisture were helpful in making improvements in the models. The Russian wheat aphid is the most cold tolerant aphid specie on the plains of Colorado. If the models indicate that 100% mortality has occurred in Russian wheat aphids, other aphids are certainly dead as well.

INTERPRETATION: These models can help predict Russian wheat aphid winter mortality. They also explain how environmental factors interact with one another to cause mortality.

FUTURE PLANS: The information generated from this study will be published. It is hoped that the models will be used in production agriculture in the future.

STRIPED FLEA BEETLE (*PHYLLOTRETA STRIATA* (F.) SURVEYS AND DAMAGE RATINGS IN EIGHT VARIETIES OF CANOLA

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USDA-ARS Central Plains Resources Management Research Unit

PROBLEM: Canola is grown for its edible oil and is being investigated as an alternative dryland crop on the great plains. In the spring 1993 it became obvious that significant leaf tissue was being consumed by flea beetles in a canola variety by fertilizer experiment on the Central Great Plains Research Station. It appeared as if some of the varieties were being damaged more than others when the canola was in the first two true leaf stage. Several beetles were collected and sent to Dr. Whitney Cranshaw, Colorado State University Extension Entomologist for identification. Flea beetle surveys and damage ratings were conducted to determine if some varieties were less susceptible to flea beetle damage than others.

APPROACH: The Experiment was set up as a split plot design, with varieties as the main plots and nitrogen rate (0, 40, 80 lb N/acre top dressed as ammonium nitrate) as subplots. The varieties were IMC-129, Cyclone, Westar, IMC-01, Alto, Global, Parkland and Excaliber planted in 9.1m x 15.2m plots.

Flea beetle surveys and damage ratings were estimated in the 40 lb N rate plots only. Flea beetle numbers per plant were estimated on 5 May 1993 by carefully approaching five random plants in each plot, and counting the number of beetles per plant. Following the visual observation, the plant was disturbed with an index finger to insure that none were missed.

Clear plastic Pan traps (12 x 12 x 3cm) were also used to estimate flea beetle populations in the 40 lb N rate plots. On 6 May 1993, the pans were filled with soapy water and placed in the center of the 40 lb N rate plots. The pans were collected the following morning and taken to the laboratory where all the beetles per pan were counted.

Damage ratings per variety were estimated by using an arbitrary rating scale from 1 to 4. The number rating 1 would be no damage, while 4 would be 90% or greater leaf area loss from flea beetle feeding. The ratings were made by two individuals on 7 May 1993, and one individual 8 May 1993.

The data (beetles per plant, beetles per pan trap, and damage ratings) were analyzed using the PROC ANOVA option from SAS (SAS Institute version 6.01). Analysis were conducted on both transformed (square root of y +.5) and untransformed data. Means were separated by student Newman Keuls test, ($P>0.05$).

FINDINGS: Identification of the flea beetles revealed that 100% of the sampled individuals sent to Dr. Cranshaw were the Striped Flea Beetle (*Phyllotreta striata* (F.). The number of striped flea beetles per plant, and per pan trap indicates that their was a high amount of variation involved with the two survey methods. The associated P and F values from the analysis of variance were not significant. The Alto variety had the highest number of striped flea beetles per pan trap, however this was not reflected in the number of beetles per plant and the damage

ratings. The data indicate that more efficient methods of surveying flea beetles and assessing damage of to plant are needed. The flea beetles are highly mobile insects and can move freely and quickly from one plot to another. The yield data are given in Merle Vigils 1993 annual report of the Central Great Plains Research Station. The data yield data probably would not reflect flea beetle damage because of hail.

INTERPRETATION: It is obvious that very little information is available on flea beetles attacking canola. The survey methods used in this study must change to more accurately estimate flea beetle numbers and plant damage. Visual observations made during the early growth of the varieties in this study appeared to show a gradient preference. However the flea beetle survey and plant survey data did not reflect a preference gradient.

FUTURE PLANS: Planting the canola varieties will be conducted for one more year. The results of determining if a variety preference of the flea beetles exits using improved survey methods would be useful, considering that there is little information available on flea beetle preference to canola varieties.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

Publications

Aiken, R., Flerchinger G., Nielsen D., Alonso C., and Rojas K. 1993. Instrumented measure and simulated solutions for the soil energy balance under residues. Agron. Abs. 85:8.

Anderson, R.L. 1993. Crop residue reduces jointed goatgrass (Aegilops cylindrica) seedling growth. Weed Technol. 7:717-722.

Anderson, R.L. 1993. Growth characteristics of winter annual grasses in winter wheat. West. Soc. Weed Sci. Res. Rpt. Chap. VI:1-3.

Anderson, R.L. 1993. Guidelines for downy brome management in winter wheat. USDA-SCS Conservation Tillage Fact Sheet #1-93. 2 pp.

Anderson, R.L. 1993. Jointed goatgrass (Aegilops cylindrica) ecology and interference in winter wheat. Weed Sci. 41:388-393.

Anderson, R.L. 1993. Managing the jointed goatgrass seed bank and assessing yield loss in winter wheat. Pages 43-47, in Proc. Jointed Goatgrass Symposium. USDA-ARS and USDA-CSRS, 79 pages.

Anderson, R.L. and D.C. Nielsen. 1993. Emergence patterns of volunteer wheat, jointed goatgrass, and downy brome. West. Soc. Weed Sci. Res. Rpt. Chap. VI:4-5.

Armstrong J. S. 1993. Annual Report of Russian wheat aphid Research submitted to the Department of Entomology and Colorado State Experiment Station, November 23, 1993.

Armstrong, J. S., F. B. Peairs, S. D. Pilcher, & C. C. Russell. 1993. The effect of planting time insecticides and liquid fertilizer on the Russian wheat aphid (Homoptera:Aphididae) and lesion nematode (*Pratylenchus thoreni*) on winter wheat. Journal Of The Kansas Entomological Society, 66(1)pp 69-74.

Blackmer T.M., J.S. Schepers, M.F. Vigil. 1993. Chlorophyll meter readings in corn as affected by plant spacing. Communications in Soil Science and Plant Analysis. 24:2507-2516.

Bowman, R. A., and A D. Halvorson. 1993. Changes in soil chemical properties under different tillage and cropping systems. Agron. Abs. 85: 268.

Bowman, R. A., and J. O. Moir. 1993. Basic EDTA as an extractant for soil organic phosphorus. Soil Sci. Soc. Am. J. 57:1516-1518.

Butts, R.A. and J.S. Armstrong. 1993. The effect of cold exposure on mortality and reproduction of laboratory and field populations of the Russian wheat aphid. *In* Proceedings of the 41st Annual Meeting of the Alberta Entomological Society, Lethbridge Alberta Canada, 20-22 October.

Cabrera, M.L., M.F. Vigil, and D.E. Kissel. 1993. Potential nitrogen mineralization: laboratory and field evaluations. Agron. Abs. pg 269.

Follett, R.F., L.K. Porter, and A.D. Halvorson. 1993. Microbial biomass dynamics using ^{15}N-labeled fertilizer in a 4 year crop rotation study. Agron. Abstracts. 85:247.

Francis, D.D., J.S. Schepers, and M.F. Vigil. 1993. Management and utilization of manure nitrogen and phosphorous for a continuous corn system. Agron. Abs. pg 271.

Francis, D.D., J.S. Schepers, and M.F. Vigil. 1993. Post-Anthesis nitrogen loss from corn plants. Soil Sci. Soc. Am. J. 85:659-633.

Halvorson, A.D. 1993. Soil: Dryland saline seeps. p.385-389. In McGraw-Hill Yearbook of Science and Technology. McGraw-Hill, New York, NY.

Halvorson, A.D., G.A. Peterson, and S.E. Hinkle. 1993. Tillage and Cropping System Effects on Dryland Wheat and Corn Production. Agron. Abs. 85:316.

Hinkle, S. E., editor. 1993. Proceedings of the Fifth Annual Colorado Conservation Tillage Association Conference. Colorado Conservation Tillage Association, Akron CO. 24 p.

Hinkle, S. E., W. L. Kranz, D. G. Watts and D. C. Nielsen. 1993. Corn crop coefficients based on growing degree days or growth stage. ASAE Paper No., 932523, Chicago IL.

Hinkle, S. E., and D. Senft. 1993. Add-on speedometer cuts costs. Agricultural Research, Vol. 41(5):22.

Johnson, C.K. 1993. Microbial respiration in soil: what are the relative contributions of bacteria and fungi? M.S. Thesis. Colorado State University Press.

Johnson, C.K., K.G. Doxtador and M.F. Vigil. 1993. Modification of substrate-induced respiration methods for the measurement of bacterial and fungal contributions to respiration in dry soils. Western Soil Science Society Agronomy Abstracts pg 2.

Nielsen, D.C, and Anderson, R.L. 1993. Managing residue and storing precipitation. Colorado State Soil Conservation Board, Denver, CO. Conservation Tillage Fact Sheet #2-93. 2 pp.

Nielsen, D.C., and Anderson, R.L. 1993. When's the best time to use paraquat on volunteer wheat? Colorado Rancher and Farmer 47(2):30,32. Feb.

Nielsen, D.C., and Hinkle, S.E. 1993. Field evaluation of corn crop coefficients based on growing degree days or growth stage. ASAE Paper No. 932524, Chicago, IL.

Nielsen, D.C., Lagae, H.J., and Anderson, R.L. 1993. Time-domain reflectometry measurements of surface soil water content. Agron. Abs. 85:16.

Paul, E.A., R.F. Follett, A. Black, A.D. Halvorson, D. Lyon, and D. Harris. 1993. Carbon dynamics of Great Plains soils. Agron. Abs. 85:257.

Pierzynski, G.M., M.F. Vigil, and D.E. Kissel. 1993. Urea-Nitric Phosphates: field and laboratory evaluations. Communications in Soil Sci. and Plant Anal. 24:1665-1682.

Pilcher, S., J.S. Armstrong, M. Koch, and F. P. Peairs. 1993. Control of sunflower seed pests with hand-applied insecticides. *In* Technical Bulletin LTB93-3, 1993 Colorado Field Crop Insect Management Research and Demonstration Trials, F.B. Peairs and S. Pilcher (eds).

Porter, L.K., R.F. Follett, and A.D. Halvorson. 1993. Plant ^{15}N uptake in a 4-year dryland rotation under no-till. Agron. Abs. 85:282.

Shaffer, M.J., F.J. Pierce, A.D. Halvorson, B.K. Wylie, and R.F. Follett. 1992. Nitrate Leaching and Economic Analysis Package (NLEAP) Model. In Proceedings of 22nd Annual Workshop on Crop Simulation.

Swanton, C.J., K.N. Harker, and R.L. Anderson. 1993. Crop losses due to weeds in Canada. Weed Technol. 7:537-542.

Toombs, M., R. Anderson, P. Baumann, and W. Keeling. 1993. Weed Management. p. 79-84. Chapter 11. In Technology Transfer Document: Crop Residue Management in the Southern Great Plains, USDA-SCS.

Vigil M.F., D.E. Kissel and M.J. Shaffer. 1993. Measured and simulated temperature effects on nitrogen mineralized from crop residue amended soils. Agron. Abs. pg 262.

Vigil, M.F., D.C. Nielsen, and A.D. Halvorson. 1993. Dryland canola production: variety selection, nitrogen response, and water use in the Central Great Plains. Western Canola Development meeting. October 21-22, 1993, Spokane, WA.

Westra, P. and R. Anderson (eds). 1993. National Jointed Goatgrass Symposium Proceedings. USDA-ARS and USDA-CSRS, 73 pages.

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MISSION STATEMENT

Provide leadership in synthesis, quantification, evaluation, and enhancement of knowledge to support the development of sustainable and adaptive agricultural production systems that are biologically efficient, environmentally sound, and economically feasible. Areas of concentration include:

(1) Production, water quality, and environmental change.

(2) Evaluation of existing management practices on a long-term basis, and developing ideas for new management practices.

(3) Use of models for regional analysis.

(4) Creation of decision support systems for on-farm management.

TECHNOLOGY TRANSFER - 1993

Great Plains Systems Research Unit

Technology Transfer has been a major effort for most of the GPSR scientists. Some major activities are:

1. Provided training on the use of NLEAP model to 18 SCS area and field-office personnel in Illinois, and 12 SCS, CSU, an d ES personnel in Colorado. We will soon start working with SCS-TSID, Fort Collins, installing NLEAP modules in their Field Office Computing System (FOCS). NLEAP will be used in conjunction with demonstration plots in Northern and Southern Water Conservancy Districts, and in the San Luis Valley of Colorado to show effects of BMPs in reducing nitrate leaching.

2. We have been working actively with MSEA projects in the Midwest on evaluating and refining the RZWQM - Root Zone Water Quality Model. The RZWQM will be used for integration and transfer of new knowledge and technology over the entire region.

3. Working with the Colorado State SCS Agronomist in using our SHOOTGRO model to simulate biomass production of winter wheat by late fall with a 90% probability in different parts of Colorado. This for their RCA compliance program. Historical weather data from a number of locations have been collected and the input parameter files are being created.

4. We have conducted a literature search for the Colorado State SCS Agronomist on the effects of common herbicides on residue decomposition, and helped plan a cooperative experimental study at Akron on this subject.

5. Our SPUR2 model is being used by SCS in Idaho, with our help.

6. GPSR scientists presented more than ten papers at professional meetings, and published more than 30 papers.

7. Development has begun for a Decision Support system, called GPFARM, for farmers and ranchers in the Great Plains. This will be a major focus of the GPSR team.

DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR FARMERS AND RANCHERS IN THE GREAT PLAINS

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G.S. McMaster, and L.R. Ahuja
Great Plains Systems Research Unit

CRIS: 5402-66000-001-00D

PROBLEM: Maintenance of sustainable agriculture in the Great Plains has become a complex problem demanding consideration of a range of interrelated factors, processes, and institutions. Across the Plains, agriculture is limited by the supplies of water and nitrogen that are available from the natural system. Supplementing these scarce resources without damaging the environment is a major challenge. Past management practices and Federal programs have created special environmental, managerial, economical, and political considerations that must be addressed. Producers must be able to adapt to fluctuations in weather and commodity prices, plus react to trends in Federal and State legislation, and to perceptions by the urban public. In the immediate future, the ability to quickly modify farm and ranch management practices to take advantage of the global economy; new cropping, pest management, and tillage systems; and new legislation while protecting soil, air, and ground water resources will determine whether an agricultural enterprise system survives or perishes.

APPROACH: A computer-based decision support system at the whole-farm level is being developed that is capable of analyzing and developing strategic 1-10+ year management plans based on the predicted productivity of selected management options and associated environmental and economic risks. The goal of GPFARM, Great Plains Framework for Agricultural Resource Management, is to provide an operational framework for farm/ranch decision support across the Great Plains including site-specific management (e.g., selection of cultivars and crop rotations, crop-animal mixes, tillage and residue management techniques, nutrient applications, irrigation management, and pest control), economic, climate, and soils information from which alternative agricultural strategies can be developed and tested. Management of water and nutrients will be stressed with strong emphasis placed on profitability and simultaneous protection of the environment with respect to soil erosion, nitrate leaching, and pesticides. GPFARM will include linkage to GIS and precision farming, use of national soil and climate databases, an object-oriented symbolic user interface, and object-oriented simulation of soil-plant-animal processes.

FINDINGS: A planning document entitled "Great Plains Framework for Agricultural Resource Management (GPFARM)" was developed to define the problem, scope, users and user requirements, and general approaches of the research project. Training in the object-oriented C++ programming language and the Microsoft Visual C++ windows development system was provided to members of the development team and other interested parties. Preliminary design work was completed on the user interface input portion of GPFARM prototype 1. This interface makes extensive use of object-oriented graphical and menu techniques to define the farm field

and management unit layout, associated attributes and operations, inputs, outputs, and internal transfers between management units. We have developed a design that allows the user to define an entire farm layout using two primary computer screens regardless of farm/ranch configuration or complexity. For example, a conventional wheat-fallow operation or a more complex organic farming enterprise with animals can be set-up using the same layout windows. Interface development is being done using Microsoft Windows 3.1 and Visual C++ and other programs, such as simulations, user interfaces, and expert systems are being coded in C++ where feasible. The Microsoft system allows direct linkages to modules compiled in other programming languages such as FORTRAN, PASCAL, and BASIC. Conceptual models for the crop and animal modules have been developed. A detailed plan has been developed to manage this large programming project. This plan includes assigned responsibility, estimates of the time required, and an estimate of the starting and ending date for each component.

FUTURE PLANS: The GPFARM science module development team will begin meeting early in 1994 to design and develop the simulation and related modules. GPFARM interface prototype 1 will be tested early in 1994 by a group of farmers, farm consultants, and extension scientists. Feedback from these interactions will be used to make refinements and changes where needed. Later in 1994, the simulation and interface modules will then be merged and the resulting prototype tested by the user consultant group. Final coding of version 1.0 of the decision support system will be completed in June, 1995.

MSEA-GPSR SYSTEMS MODELING EXERCISE

Root Zone Water Quality Model Development Team:
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PROBLEM: The MSEA modeling group and the USDA-ARS Great Plains Systems Research (GPSR) unit have been working in a close cooperative effort to improve and validate the Root Zone Water Quality Model (RZWQM). The goal of the work is to improve the model so that it can successfully simulate the complex management systems being studied at the MSEA sites. With that accomplished, the model will be used to study the potential impact on water quality of modifying practices in different management systems, over a wide range of soil and climatic conditions. In particular, application of the model will help to transfer the knowledge gained from the MSEA projects to areas with conditions different from the sites.

APPROACH: Each MSEA location has the responsibility for evaluating and improving a major process within the model. These processes include nitrogen cycling, transformations, and transport in the root zone (Nebraska), pesticide degradation and transport (Iowa), surface runoff and chemical transport (Missouri), infiltration and preferential flow (Minnesota), and plant growth dynamics and parameterization (Ohio).

In a highly integrated model such as RZWQM, it is important to become aware of how the system as a whole operates, so that the ramifications of possible improvements would be adequately understood. This report describes the result of an exercise conducted by the joint group to verify that RZWQM can adequately simulate the diverse environmental conditions present at each site. To facilitate the verification process, each MSEA site developed a set of input data representing a commonly used management system in the region of the site. These data sets were run through the model and the resultant output critically evaluated to find both programming errors and conceptual problems in system simulation.

The MSEA scientists worked closely with members of the RZWQM development team to insure that suitable input parameters were used and an enhanced understanding of the model components would be gained. When appropriate, model changes or enhancements were to be made so that the utility of the model both for this example and for subsequent use would be increased. The problems that were found and the changes that were made are described in this report.

The next phase of this effort will be to compare detailed process simulations with the base data sets. The model processes as outlined above, will be validated against MSEA site field data.

This should provide insight for suggesting additional model changes and improvements. This collaborative effort should yield a greater understanding of the field data, and a vastly improved version of RZWQM.

FINDINGS: Several simulation problems have been identified through the collaboration of the GPSR unit and the MSEA modeling group. The severity of these problems has ranged from very simple programming oversights to inadequate characterization of input values, and the need for modifications in some parts of an overall process. Due to the highly integrated nature and completeness of the processes modeled within RZWQM, a relatively small error in programming or out-of-bounds input data could potentially propagate errors throughout the model and cause catastrophic results.

The diversity of the MSEA data sets and the critical examination of the model results has combined into the most thorough examination of RZWQM thus far. The efforts of the MSEA scientists in identifying errors in the model output have been exceptional. Major problems discovered and mostly corrected are listed below. Most were found through cooperation with a MSEA scientist. The minor model errors will not be listed, while they also have been corrected.

☐ Concentrations of soil weight based constituents not updated. Certain model constituents, such as soil humus pools, microorganism pools, and adsorbed chemicals, were not updated as horizon bulk densities changed after tillage. Whenever a change in bulk density occurs, all the soil weight based concentrations are now updated.

☐ Initial tillage layers were incorrect. To effectively till the soil, we adopted a procedure originally from the WEPP model, in which two tillage zones or horizons were created to accommodate the tillage implements specified by the user. When these horizons were created the model incorrectly partitioned the horizon constituents and thicknesses.

☐ Redistribution of soil water was not occurring during infiltration. We use a Green-Ampt infiltration scheme for routing water during a rainfall event. This scheme efficiently moves a wetting front through the soil, but does not allow for water movement below this front. The latter becomes significant during low intensity, long duration events. A new routine was introduced to allow for gravity induced flow of water and chemicals below this wetting front.

☐ Under certain conditions, such as during periods of extreme soil evaporation potentials or following a heavy rainfall event on a dry soil, the numerical scheme for solving Richards' equation failed to converge. We have implemented an approach to solve this problem that allows for the time step to be cut by many orders of magnitude until convergence occurs. This unfortunately, has not solved the problem for all cases and we have now introduced dynamic grid generation, to achieve the most robust numerical scheme for this difficult problem.

- ☐ Model pH values were not responding as expected. Initial predicted values of soil pH were fluctuating erratically, although a buffer system was specified. It turned out that a conversion factor used during the development of the equilibrium soil chemistry submodel was still being used. This caused the partial pressure of CO_2 gas to be converted to millibars instead of atmospheres as expected in the model.

- ☐ Nutrient system was not responding to temperature fluctuations. Temperature dependent processes within the nutrient submodel such as nitrification, mineralization, and denitrification were nonresponsive to changes in soil temperature. The governing Arrhenius equations had to be modified to allow for a more balanced effect from temperature and other environmental factors.

- ☐ Initialization of the nutrient system was not clear. The solution scheme used to solve the nutrient cycle requires that the carbon and nitrogen in the system be partitioned between 14 different pools. The pools of the most concern were the three soil humus and three microorganism pools. The partitioning of data collected from a simple soils report into the expected humus pools had to be better defined so the MSEA scientists could give reasonable estimates from their site. Partitioning into the three microorganism pools follows observations from literature. A detailed document and a practical example contained within a working spreadsheet were supplied to each of the MSEA sites to provide guidance. This solution is to be included in future versions of the model documentation and user's manual.

- ☐ The plant model needed a reexamination of the corn parameterization, nitrogen demand, root/shoot ratio, progression through growth stages, carbon translocation, and biomass production. Since crop yield was a required outcome from the evaluation of each MSEA site, the plant model should respond to environmental effects properly. The biomass and nitrogen yield from the model now are in line with what is expected.

- ☐ Nitrogen extraction from the soil profile by roots needs further analysis. Comparison of seasonal and daily totals with literature values implies that the root nitrogen extraction model may need to be refined. The current formulation assumes a linear extraction of soil nitrogen. A more eloquent diffusion driven system may yield better results.

INTERPRETATION: Many lessons have been learned from this experience. The modeling work has helped the developers of RZWQM and helped MSEA scientists learn more about their sites. From the developers point of view, the lesson that stands out most is that a highly integrated process based model has large and stringent data requirements. The processes contained within RZWQM are at the current state-or-the-art class of science and have the same level of complexity or completeness throughout; the data requirements for these processes can be demanding. We purposely provided for user input into low levels of operation of detailed processes, so that researchers could manipulate these processes and see how they affect the whole main process. This makes the model operation highly dependent on the input data that control each process. The result is that most data elements have importance and there is not a generic sense given to any of the model components. MSEA scientists had to interact with their

colleagues involved in many different scientific disciplines at the site to fully parameterize the model. Occasionally, additional measurements or analysis had to be completed, in order to gain a better perspective of the system.

The requirement of a large input set suggests that a thorough sensitivity analysis be undertaken to identify the most important parameters. This analysis should be done at two levels, one at the individual process level, and secondly at the whole model level. The highly interrelated nature of RZWQM could show the whole model analysis to be much different from the individual process analysis.

Each MSEA site created a data set that satisfied the requirements for a common management scenario and model expectations. The resulting data sets provided an excellent testbed to exercise the model with and gave the model developers a good view of model operation. During development a modeler gets a narrow and highly detailed look at model operation on a day by day basis, but lacks a broad and critical view. Using all these different MSEA data sets has provided an opportunity to look at the broad effects of process interaction and dependence. This diverse testing has given RZWQM developers much more confidence that the model components are responding properly.

An initial 3-day training session on model operation and parameterization was provided to MSEA scientists. This proved not to be very effective. A series of less intense sessions with much more hands on experience would probably be more desirable when future versions of the model are introduced.

Updates to the documentation would be helpful. The model has gone through many changes since this collaboration began. Unfortunately, the documentation has not kept up with the code changes. When possible brief segments of written information, as mail or newsletters, have been distributed to users. Often the definition of an input variable by a RZWQM developer, may not coincide with that of the MSEA scientist. Clear and thorough definitions of all the input variables could help future users gain a good understanding of the model and it's inputs more quickly.

The use of the internet for communications and file sharing has been an enormous benefit for the whole process. Through the use of the internet, information on model problems and fixes has been sent out, and quick access to current data sets and model updates has been invaluable.

FUTURE PLANS: Version 2.0 of RZWQM is under development. Many improvements and extensions have been made to enhance the model's ability to simulate more diverse situations and answer concerns brought forth by MSEA scientists. The following additional enhancements are being made for version 2.x of the model:

☐ The model will be a four-season model and include freezing and thawing of the soil water, and also snow cover and melt. Up to this point model simulations have been limited to situations where ice and snow were not a factor.

- ☐ Improved versions of the evapotranspiration and heat flux submodels will include the effects of a residue cover (mulch). This incorporates an improved energy balance, hourly diurnal distributions of the two main driving variables (air temperature and incoming shortwave radiation), and effects from snowpack insulation.

- ☐ Addition of a fluctuating water table in the root zone with flow and transport to tile drains.

- ☐ The residue (mulch) system of the model will be greatly improved. The residue layer will be a much more dynamic system with the addition of surface manures including bedding materials, decomposition of the mulch layer with leaching organics, and more thorough insulation effects on surface heat flux.

- ☐ Improved versions of the macropore flow and transport routines.

- ☐ Plant growth processes will be extended to include soybean growth through our generic plant growth model. Optional use of alternative growth models of corn taken from the Ceres-Maize model and soybean taken from the Soygro model.

- ☐ Improved pesticide sorption kinetics.

EVALUATION OF RZWQM FOR SIMULATING WATER AND AGROCHEMICAL FATE

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PROBLEM: Fate and behavior of agrochemicals in the environment can be effectively evaluated by validated model(s). Several chemical fate models have been developed since the middle of the 70's, but few have been validated. This extremely limits their applications. The ARS Root Zone Water Quality Model (RZWQM) is being evaluated against data from a number of locations.

APPROACH: Data on water and chemical (bromide, atrazine, cyanazine, metribuzin, and nemacur) movement and chemical transformation were collected from laboratory in Tifton, GA and from fields in Watkinsville, GA and Wageningen, The Netherlands. Those data were used to evaluate the RZWQM performance on simulating water and chemical movement (leaching and runoff) and chemical adsorption and transformation behavior. Model evaluation (comparison with observed data) was done by both graphical comparison and statistical analysis.

FINDINGS: The following model outputs were compared with the observed data: 1). soil water distribution; 2). water runoff; 3). atrazine in runoff water; 4). chemical (atrazine, cyanazine, metribuzin, and nemacur) persistence in the soil profile; 5). bromide distribution in the soil profile (both in packed soil boxes and in the field); 6). distributions of atrazine and nemacur in packed soil boxes and in percolation water, and distributions of atrazine, cyanazine, and metribuzin in the soil profile (field). Results showed that the model could reasonably simulate water and chemical movement and chemical transformation in the soil profile. In the testing processes, we did find that the differences between measured and simulated water and chemical runoff were much more than those of water and chemical distributions and chemical persistence in the soil profile. This probably results from variabilities of the watershed topographic shape which the RZWQM does not account for.

FUTURE PLANS: Tests of the model so far have shown that the model did simulate water and chemical distributions as we expected. Further validation of the model will focus on how well the model simulates water and chemical fate under different management practices conditions. Refinement will be made in water and chemical runoff part of the model. We have planed an experiment on water and chemical movement under different management practices in a sandy soil and will implement the model with these data.

ROOT ZONE WATER QUALITY MODEL EVALUATION OF DRYLAND AND IRRIGATED CROP PRODUCTION SYSTEMS IN COLORADO

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PROBLEM: Water conservation and quality are two of the main concerns shared by many in Colorado. The ability to mathematically model agricultural crop production systems is an invaluable tool to study the effects of various management practices on water conservation and quality. The ARS Root-Zone-Water-Quality Model (RZWQM) is an integrated physically-based model that simulates the many physical, chemical and biological processes in the soil-crop-atmosphere continuum. Because of the complexity of natural systems, model performance and applicability are best determined through its exposure to a wide range of conditions.

APPROACH: A significant portion of time in 1993 was devoted to model verification of the evapotranspiration (ET) sub-model and incorporation of the CERES-MAIZE (VER. 2) plant growth model in RZWQM (in cooperation with Dr. Tom Hodges, USDA/ARS). The strengths and weaknesses of RZWQM were then evaluated using a dryland (under a wide range of cropping sequence) and irrigated (center pivot and furrow) corn production systems in Colorado. The first phase of this endeavor was completed in 1993, in which measured climatic, crop, soil physical, chemical and hydraulic parameters and irrigation, pesticide and fertilizer applications were collected for model evaluation. The selected projects significantly differ in management practices of agro-chemical application, irrigation and tillage. Modeling of dryland/no-till crop systems was selected (in cooperation with Dept. of Agronomy, Colorado State University) to mathematically investigate the effects of no-till/residue covered technique on water conservation and nitrate movement. Three sites, located near Sterling, Stratton and Walsh, were chosen in Eastern Colorado that represent a gradient of potential evapotranspiration. The second project involved application of RZWQM to a farmer field center pivot irrigated corn in Eastern Colorado. This study was originally initiated by the Water Management Research Unit in 70's to address water management effects on both root zone and ground water NO_3-N loading. Since reliable measured data of root zone loading and ground water leaching of nitrate are available, the simulation efforts of this project are expected to evaluate RZWQM capabilities as to model sprinkler irrigated crop systems with emphasis on solute transport within and below the root zone. The third field research project was initiated in cooperation with the Water Management Research Unit during the 1993 growing season to collect accurate and adequate data from an alternate furrow irrigated corn field north of Fort Collins. One of the main objectives of this collaborative work is to validate RZWQM simulation of furrow irrigated corn and to evaluate the sub-models of evapotranspiration (the Shuttleworth-Wallace Sparse canopy evaporation

model) and the plant growth. This particular field was intensively instrumented to quantify ET (using Bowen ratio setups), boundary layer wind profile, soil water content, root distribution, climatic variables, plant biomass and yield, corn stomatal resistance, canopy cover, canopy temperature, and soil heat flux. The experimental phase of this research was completed in late October. Analysis and interpretation of data are currently underway.

FINDINGS: Verification of the ET sub-model (the Shuttleworth-Wallace model) yielded deficiencies in the wind profile adjustment, soil albedo, aerodynamic resistances and residue evaporation algorithms. The ET sub-model was thoroughly evaluated and subsequently modified. The Shuttleworth-Wallace Sparse Canopy ET model was re-derived to incorporate evaporation from residue covered soils by imposing an additional resistance to soil evaporation. The CERES-MAIZE plant growth model was successfully incorporated in RZWQM, thus providing the user with alternative plant growth models. Application of RZWQM to a center pivot irrigated corn field in Prosser, Washington yielded similar results when the CERES-MAIZE plant growth was used as compared to the Generic plant model. Site evaluation and collection of reliable input data for model evaluation of dryland and irrigated crop production systems were completed in 1993. The magnitude of the available information from these projects is overwhelming, requiring systematic validation efforts well into 1994. Preliminary model simulation results are promising as RZWQM shows sensitivity to climatic, soil and management practices.

FUTURE PLANS: Using the revised and significantly enhanced version of RZWQM (VER. 2.0), the strengths and weaknesses of RZWQM will be evaluated using the information collected from Colorado dryland and irrigated crop production systems. We will investigate whether soil evaporation in dryland/no-till practice is the dominating mechanism increasing water use efficiency. In the center pivot irrigated corn project, water contents in the root zone and nitrate contents of the percolates will be used for model evaluation of ground water contamination. Minimizing deep percolation of irrigation water should increase nitrogen use efficiency and decrease water quality degradation from nitrate and other solutes. RZWQM will be utilized as a research tool to evaluate alternative management practices that would lead to water conservation and quality. Three abstracts have been submitted for publication and presentation at the 1995 International Symposium on Water Quality Modeling (sponsored by the ASAE).

MODELING FLUCTUATING WATER TABELS AND TILE DRAINAGE WITH THE ROOT ZONE WATER QUALITY MODEL

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PROBLEM: The Root Zone Water Quality Model (RZWQM) is presently undergoing extensive evaluation at several locations, especially in the Midwestern states participating in the Management Systems Evaluation Areas (MSEA) projects, for quantifying and analyzing effects of agricultural management systems on ground and surface water quality. Presently, the model does not simulate fluctuating water tables in the root zone and tile drainage conditions that occur in several parts of the Midwest (especially Iowa, Ohio and Missouri). In these areas, the groundwater table rises into the root zone during the crop growth period and drainage is necessary. These high, fluctuating water tables and any installed drainage practices not only affect the crop growth significantly, but may also affect both groundwater and surface water quality in a major way.

APPROACH: In order to analyze the water quality effects, MSEA scientists asked us to incorporate a fluctuating water table and drainage conditions into RZWQM. Thus, additions and modifications to the water movement module (newly named RZWFLO) in RZWQM have been made for such purposes. To test the modified numerical scheme, we simulated field data from a site at the H. Carroll Austin farm near Aurora, NC, which has been used in several previous studies. Data from three drainage treatments, consisting of tiles spaced 7.5m, 15m and 30m apart, were available for three years (1974-76). The observed data included daily midpoint water table elevations, outlet ditch elevations, hourly precipitation and daily potential evaporation. The predicted daily depth of the water table were compared to observed data and to results from previous models and a more rigorous new numerical model (WAFLOWM), which contains an optimizing dynamic gridding scheme.

FINDINGS: The models predicted water table depths which were comparable to those observed and those simulated by previous models. In general, results of the RZWFLO and WAFLOWM models are as close or closer to the observed data than those of the three previously used models for 7.5 and 15m drain spacings, but worse for the 30m spacing. Predicted results for the 30m drain spacing have a larger standard deviation than those for the other spacings, possibly due to the increase in 2-dimensional effects as drain spacing increases. In RZWFLO, the modified numerical scheme worked well in maintaining mass balance, and run times for a full year of data remained reasonable (15-20 min. on a 486/66 personal computer).

INTERPRETATION: The modifications made to the water movement module, excluding the tile drainage equations, can be incorporated into RZWQM to simulate fluctuating water tables

in the root zone. Although the equations used to calculate tile drainage and subsurface irrigation worked fine in this approximation, they are not general enough for use in RZWQM.

FUTURE PLANS: Changes to the water movement module made during this study have been incorporated into the full RZWQM, and a new equation for tile drainage has been implemented. Before releasing the modified model, it remains to validate these changes by comparison to field data on both water and chemical transport. We can then study chemical transport and the effects of various management methods on soils with a water table in the root zone. This would be very useful in the study of water quality and crop management in these soils.

ROOT ZONE WATER AND CHEMICAL TRANSPORT AS ALTERED BY MACROPORES

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PROBLEM: The work done by soil physicists over the last few decades has greatly enhanced our understanding of the water and chemical transport processes. However, not enough has been done to fully understand and quantify the effect of management practices. Yet, it is only through management practices that we can have some degree of control over these processes. Preferential flow paths and crop rooting patterns are, in a sense, a manifestation of certain management practices.

The major thrust of this work will be to develop basic understanding and theoretical framework for water and chemical transport processes in a field as influenced by soil conditions, such as macropores, and practices such as type of tillage, cropping, surface cover, chemical placement, and surface shaping. Special emphasis will be on the dynamics of a row-crop system of corn or soybeans, planted on lands of varying topography and soil profile characteristics. Effects of rooting systems on decayed root channels, earthworm activity, and spatial non-uniformity of water and chemical transport will be of great interest. The row-crop situations often involve 2--dimensional spatial changes as well as temporal changes in soil properties and surface conditions, and 2- or 3-dimensional water flow and chemical transport pathways. Basic knowledge and theory of processes under these conditions are very limited or essentially lacking at present. This information must be developed if we are to prevent ground and surface water pollution from agricultural chemicals, while maintaining and enhancing crop production.

Specific Objectives During 1993

Analysis of data collected in a series of column studies to quantify the transfer of soil surface--applied chemicals to macropores and their downward transport through the root zone. Then, evaluate and refine a simple model of macropore transport of a surface-applied chemical (RZWQM).

APPROACH: The experiments conducted on sixteen sectionable columns, 30 cm long, 15 cm dia, packed with a Kirkland silty clay loam (Udertic Paleustoll) consisted of eight treatment combinations, each in duplicate, of the following conditions: soil initially air-dry vs. soil initially wetted by rainfall to a depth of 7 to 11 cm; a 1.5-cm layer of dry 4.7- to 12.5-mm size aggregates on the surface vs. no aggregates; and a 3-mm artificial macropore made along the column's vertical axis vs. no macropore. A 18.2-ml solution of $SrBr_2$ was atomized over the surface, followed by application of simulated rainfall at 8.5 cm hr^{-1}. In columns without a macropore, surface runoff rates and its Br and Sr contents were measured. In columns with a

macropore, all the overland flow generated went into the macropore, and macropore outflow rates through the column bottom and its Br and Sr contents were measured. At the conclusion of rainfall, the soil column was quickly sectioned in mostly 1-cm increments, with a bottom 5-cm increment. Water content, bulk density, and Br and Sr contents of these sections were measured to obtain the movement of chemicals in soil. The macropore model used to simulate this experiment is a part of the ARS soil-plant-climate-management model called RZWQM (Root Zone Water Quality Model).

FINDINGS: Without a macropore, the surface aggregates reduced the overall movement of Br in soil, and increased Br in runoff; the effects being much greater in prewetted columns than in initially air-dry columns. With a macropore, the aggregates had a similar effect on Br movement in soil, increased Br in macropore flow, and increase Br content of a wetted ring around the macropore below the main wetting front. The macropore, by itself, without surface aggregates, did not cause much difference in Br movement in the initially dry soil; in the prewetted columns, however, the macropore reduced the movement of the main Br pulse, and increased Br content of the wetted soil ring below the main wetting front. The aggregates or the initial condition did not change the Sr movement much; but the aggregates certainly increased Sr content of runoff or macropore flow.

Evaluation of the model simulations against the above data resulted in the following findings and refinements: (1) The viscous resistance and entrapped air correction factor for the Green-Ampt infiltration rates may vary with the soil wetting history, with higher values in prewetted columns, possibly due to surface consolidation and sealing caused by drainage between rainfalls; (2) The effective sorptivity of the macropore wall for lateral absorption needs to be adjusted for compaction, in addition to entrapped air, and requires further refinement, probably due to the existence of the assumed zero water pressure over only part of the pore circumference (and negative pressure over the rest) under small macropore flow rates; (3) In the wetted portion of the soil profile, the macropore flow, as it flows down, mixes with about 0.5 mm of soil around the walls and collects or loses some chemical in the process; and (4) Microporosity of surface aggregates was an important factor that held back chemical near the surface, but this chemical was available for mixing with rainfall, thus increasing the transfer to runoff or macropore flow. With the above refinements, the model simulations gave generally good descriptions of the experimental data, considering the complexity of the processes.

INTERPRETATION: The results of the experimental column studies show the dramatic effect of a 1.5-cm thick layer of soil aggregates on the movement of a mobile chemical, Br, in soil, as well as on the amount of this surface-applied chemical that is transported in macropore flow to deeper depths. These findings have important implications for interpreting and modeling the transport of surface-applied fertilizers and herbicides under field conditions. The findings also suggest that promoting surface soil aggregation will reduce leaching of surface-applied agricultural chemicals in general, especially where surface runoff is not a problem, e.g. under no-till and residue cover conditions, and in soils with high infiltration capacity.

The simulation of this data using RZWQM enhanced our knowledge of the complexities involved in modeling macropore flow. Refinements of the model should increase our ability to predict the effects of management practices on soils containing macropores and surface aggregation.

FUTURE PLANS: The model is being used to quantify and interpret the extensive field data on the transport of nitrate and pesticides to surface and groundwater from MSEA sites in the midwest. Further experiments will be conducted in soil columns in which plants are grown, to study the macropores generated by decaying roots, and their effect on preferential water and chemical movement.

NLEAP TECHNOLOGY TRANSFER AND DEVELOPMENT OF REGIONAL DATABASES

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PROBLEM: Given the current state of the national farm economy and the renewed concerns about groundwater pollution from nitrates and pesticides, there is an urgent need to find ways to optimize on-farm productions for profit and yet minimize adverse environmental impacts. Time is a critical factor in the overall problem, and we cannot afford 10 or 20 years of additional field research before optimal systems are identified. In addition, while existing data sets provide long and short term information at selected sites, they do not begin to cover the range of soil, climate, and management combinations which are encountered in the field. Farm and natural resource managers lack suitable tools which can provide answers now before additional damage is done to the farm economy and the nation's soil and groundwater resources. The NLEAP model is available for use. At a minimum level, the user needs to know how to acquire and input data, initiate the simulation, and access the simulation results. However, effective use of a simulation model requires the user to understand the system being simulated well enough to provide proper data input and to interpret the simulation results.

APPROACH: To help solve these problems, models and databases suitable for development and analysis of total crop production systems are urgently needed for use in agriculture. These models should integrate (1) the biological, chemical, and physical factors, (2) cultivars and management practices, and (3) physiological responses of crops to their environment into simulations of total agricultural systems for determining the limits and sustainability of agricultural production in semiarid agroecosystems of the Great Plains and elsewhere in the United States and the World.

FINDINGS: The NLEAP model is one of 5 water quality models being adopted for use by the U.S. Soil Conservation Service (SCS). A SCS national model leader (Dr. Stephanie Aschman, Portland, OR) has been appointed for NLEAP. In order for the SCS to effectively use the model, and use it correctly, certain groups of individuals within the agency must know the model well enough to provide in-house model support and model training. We have been working closely with SCS in formulating what model technology needs to be understood by the SCS national model teams for model support and training of state SCS personnel, how this information might be transferred to the national model teams and from them to the state SCS personnel, and the content and supporting documentation for these trainings. The current working plan developed in October of 1993 is for SCS personnel and ARS personnel to jointly provide an "embedded technology" session via satellite and video tapes followed by a week

training session on each model to train the national model team and NTC model leaders. The model training will be conducted by the model developers. The national model team and NTC model leaders will then design and provide training to state personnel.

NLEAP training courses continue to be provided on a regular basis each year. This training is attended by students, SCS personnel, consultants, and extension personnel. Training consists of a 3 day course on how to use NLEAP, on the nitrogen and water budgets under cropping systems, and on nitrate leaching problem identification and solving. NLEAP was also used in a 3 day SCS training to convey the concepts of nitrogen and water budgets and nitrate leaching under cropping systems. Along these lines an ASA poster presentation was given on using the NLEAP program as a teaching tool. A short 2 hour presentation was given to a CSU class on mechanics of the program. The class was using the NLEAP program for a class project. Individual instruction and model support is also given.

The NLEAP Soil and Climate databases continued to be developed, tested and published. The raster map products of soil survey areas of the U.S. and climate stations with evaporation for the US, developed in 1992, were used to define data availability in the Western U.S. The west was subdivided into regions with WEST1 having the most complete data available to draw upon for NLEAP. The WEST1 Database includes soils and climate for Arizona, Colorado, Nevada, New Mexico, and Utah. Regression relationships to predict evaporation, especially in winter, were developed for the WEST1 region.

Products of this research in 1993 include an update on NLEAP Southern Database Version 1.2 through ARS and publication of NLEAP WEST1 Database Version 1.2 through the Soil Science Society of America.

FUTURE PLANS: Details of NLEAP embedded technology will be presented and recorded as part of a joint SCS/ARS satellite broadcast and professional studio recording session in front of a live audience. Tapes will be available for viewing at later dates. Specialized training in the operation and use of NLEAP will be provided to selected SCS training staffs.

NLEAP database development will continue for the remainder of the western U.S. and include investigating additional data resources, and approaches to estimating winter evaporation/sublimation.

APPLICATION OF THE NLEAP MODEL TO REGIONAL NITRATE LEACHING IN COLORADO

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PROBLEM: High levels of nitrate-Nitrogen (NO3-N) in drinking water supplies pose health risks to humans and livestock. Groundwater is an important source of drinking water in the United States. The U.S. Environmental Protection Agency has established 10 mg/l as the safe level on NO3-N in drinking water. NO3-N in and derived from fertilizers and manures applied to croplands can be moved into underlying aquifers if NO3-N is available for leaching during an event of deep water percolation below the crop root zone. This nonpoint NO3-N pollution is prevalent in areas with alluvial aquifers where aquifers tend to be shallow and soil profiles coarser (sands and gravels). Farmland management of nitrogen and (in irrigated regions) water need to be carefully considered on areas vulnerable to NO3-N leaching. The identification and mapping of spatial patterns in groundwater NO3-N concentrations and NO3-N leaching vulnerability across an area will result in more effective remediation of the problem by focusing efforts on problem areas and possibly give indications about part sources of NO3-N in the aquifer.

APPROACH: Mechanistic modeling and Geographic Information System (GIS) technologies have been combined to map simulated NO3-N leaching in an area in northeastern Colorado where irrigated agriculture occurs over the shallow South Platte River alluvial aquifer. The Nitrate Leaching and Economic Analysis Package (NLEAP) was selected as the process oriented mechanistic NO3-N leaching model. By combining spatial GIS coverages for alluvial aquifers, irrigated agriculture, center pivots, and county soil maps combinations scenarios for model simulations were identified. Resulting maps of NLEAP indices were smoothed with an averaging filter so that each grid cell in the map represented the average of an area comparable the area an irrigation well would draw from. Correlations between NLEAP indices and groundwater NO3-N was from pumping irrigation wells sampled during the growing season from 1989-1991.

FINDINGS AND INTERPRETATIONS: NLEAP regional simulations are a useful tool in identifying areas vulnerable to NO3-N leaching. Long term steady state simulations were better correlated to groundwater NO3-N concentrations than single year simulations (Wylie et al. in press-a). Single year simulations are sensitive to residual soil NO3-N levels at the beginning of simulation. Given that residual soil NO3-N levels are vary as a function of past management (Ball et al. in press-a), the regional assumption of a uniform residual NO3-N level of 112 kg/ha tends to muffle the effects of different soils on NO3-N leaching unless simulations are carried to long term steady state.

Comparisons of groundwater contamination parameters showed that the concentration of NO3-N in the groundwater was more strongly correlated to regional NLEAP indices than the aquifer N mass. The NLEAP indices and derived which had the strongest correlations to groundwater NO3-N concentration were the mass of Nitrate Leached (NL), Nitrates Available to Leaching (NAL) and the concentration on NO3-N in the leachate, respectively. In this study area the concentration of the NO3-N in the leachate was less indicative of groundwater NO3-N contamination than the mass on Nitrates Leached (NL). Best Management Practice and farm management evaluation in this area should be based on the mass on NO3-N leached and not the concentration of NO3-N in the leachate.

The simulation of manure applications in the proximity of feedlots was an improved correlations between regional NLEAP indices and groundwater NO3-N (Wylie et al. in press-a). Given that soil variability was taken into account in the regional NLEAP simulations, the next most significant complimentary parameter was proximity to feed lots (Wylie and Shaffer in press). Analysis of a region north of Greeley, Colorado indicated that regional simulations that took into account proximity to feedlots and not soils had the strongest correlation to groundwater NO3-N concentrations (Wylie et al. in press-b). Variation in NLEAP simulated NL associated with soils had the second strongest correlation to groundwater NO3-N concentrations and was complementary to the NL associated with proximity to feedlots. Manuring practices along the South Platte seem to be an important factor related to groundwater concentrations. Management techniques should be developed to specifically address manure applications and also fields with histories of heavy manure applications.

Expansion of the data handling capabilities of NLEAP for construction of NLEAP scenarios from system components is being tested. The modification includes overlaying and integrating system components (such as crop, nutrient, soil, and climate). This modification will facilitate running crop rotations, steady state simulations, and the construction of NLEAP scenarios identified by GIS.

FUTURE PLANS: The regional application of NLEAP will be of an expanded area in northeastern Colorado in mainly in Weld and Morgan counties and contiuation of similar efforts intiated in the San Luis Valley in southcentral Colorado inconjunction with the SCS and ARS Soil and Plant Nutrient . A farm survey will be conducted to allow regional NLEAP simulations to better reflect the actual practices and management techniques employed by farmers along the South Platte River. Management alternative that will reduce NO3-N leaching from irrigated agricultural lands will be screened and compared via NLEAP simulation and selected management alternative demonstrated on a field with a center pivot irrigation system, furrow irrigation and a past history of manuring, and furrow irrigation on a coarse textured soil.

DEVELOPMENT OF IMPROVED SYSTEM MODELS AND TECHNOLOGY FOR SUSTAINED RANGELAND PRODUCTION

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CRIS: 5402-11660-001-00D

PROBLEM: Rangelands are economically and socially important throughout the US. In the seventeen western states, rangeland ecosystems occupy over 900 million acres and are the economic foundation of many states and communities. In some regions, rangeland products are the sole source of agricultural income. Rangelands also produce a large variety of other goods and services including water, timber, recreation, wildlife, and scenery. Most range scientists and technicians feel rangelands are producing approximately 50% their potential. The SCS recognizes that privately owned grazing lands are basic to environmental, social, and economic stability. Opportunities for enhancing the effectiveness of operators of private grazing lands include:

- Increase economic, environmental, and social stability.
- Increase awareness and perception of needs and opportunities.
- Increase information base from which to make policy and management decisions.
- Reduce the time between availability of knowledge and application.
- Enhance the land owner's ability to achieve greater profitability on an ecologically sound and sustainable basis.

APPROACH: Enhanced ecosystem models and carefully planned greenhouse and field experiments will be used to investigate the impacts of currently accepted rangeland management practices (particularly stocking rate and grazing systems) on the quantity of water-yield for on-site and off-site use, increase understanding of the plant/animal/soil interactions, and assist in the development of sustainable management strategies. Work done through this project will support a separate project that is aimed at developing the GPFARM (*Great Plains Framework for Agricultural Resource Management*) Decision Support System (see CRIS 5402-66000-001).

FINDINGS: The soil organic matter model of SPUR was replaced with a three-compartment model in SPUR2. As stocking rate increases, economic return is being substituted for the soil resource; as time passes, the loss of soil resource affects animal weights and maximum net returns more and more severely. Below-ground processes need to be evaluated further to determine the potential long-term impact of climatic change on grassland ecosystems. Measurements of various soil and plant parameters were made on a north facing slope, an

adjacent south facing slope and a nearby playa. Bulk density, texture, root biomass, soil carbon, and soil nitrogen were measured from a point grid on the sites. Moisture desorption curves were determined. The strongest spatial relationships for bulk density, 0 kPa, and 33 kPa occurred on the north slope. The sand and clay content of the south slope showed high spatial correlation. The playa displayed low spatial correlation for all of the measured parameters. These results show that spatial variability does bias estimates of many of the commonly used soil parameters. Care must be taken in quantifying the spatial variability of plant and soil parameters particularly if these parameters are going to be used in simulation models to predict effect of management strategies at the regional scale.

INTERPRETATION: Questions concerning agricultural sustainability must be addressed before recommending management strategies to Great Plains farmers and ranchers. In natural grasslands, the key indicator of sustainability is soil organic matter. Many management schemes actually decrease soil organic matter, even though they increase short-term economic returns. Using assessment models for predicting future response to anticipated management changes can improve our ability to set policy and make management recommendations.

FUTURE PLANS: To improve the utility of the tools used to assist in making management decisions, we will (1) evaluate existing process-based range-livestock system against existing data and make refinements to the models that will reflect the current knowledge of range-livestock systems, (2) convert existing Systems model(s) to modular form and make enhancements for SCS and other end users, (3) develop and test decision support sytems for easy use at the ranch scale, (4) investigate the effect of grazing systems, stocking rate, and water and nutrient distribution on carbon allocation, root growth, and water/nutrient uptake of rangeland plant species, (5) enhance and validate a plant biography model that predicts seed germination, emergence, and establishment of rangeland plants, (6) assess the impact of climatic change at the scale of the individual rancher to determine appropriate adaptive management strategies to enhance sustainable cattle and rangeland production, (7) characterize water conservation effects of current and potential grazing management practices, taking into account spatial variability of soils and patchiness of vegetation, (8) characterize effect of different small-scale spatial patterns of vegetated and bare areas, created by different grazing intensities, on infiltration, evaporation, plant water use, and plant growth, and (9) evaluate and refine process-based models of water quantity and quality for special rangeland conditions.

DEVELOPMENT OF IMPROVED SYSTEM MODELS AND TECHNOLOGY FOR SUSTAINED RANGELAND PRODUCTION: CLIMATE CHANGE

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PROBLEM: Climate models are predicting that increased in anthropogenic "greenhouse" gases will alter temperatures and precipitation patterns over large areas of the globe. Other environment effects include alterations in biogeochemical cycles, soil evaporation, groundwater storage, and plant transpiration. Changes such as these may lead to an increase in the degradation or desertification of semi-arid rangelands.

APPROACH: The objective of this research was to develop a methodology for identifying areas that would be most vulnerable should climate conditions become more harsh. These areas or regions could then be used as simulation sites for climate change assessments studies. To accomplish this objective, a Socio-Ecological Risk Index was developed in a Geographical Information System (Baker and Hanson 1993). The index was constructed from several map overlays of economic dependency on rangeland livestock production and rangeland plant and soil conditions. The purpose of the index is to locate areas where degradation of rangeland are most likely to occur and where degradation would have economically significant societal impacts. The inherent assumption of the index is that ranchers who live in these areas are economically dependent upon rangeland livestock production and do not have the natural resource base to switch to cultivated agriculture for an alternate source of income. In other words, should the rangeland resource deteriorate to the point that livestock production became unfeasible, agriculturalists in this area would be forced to migrate to new locations or seek other sources of income.

FINDINGS: Results from the study show that several areas in the western United States are potentially vulnerable to changes in climatic conditions. The largest areas that would be susceptible to degradation are located in Nevada and the four-corners region of Arizona, Utah, Colorado and New Mexico. Further assessment is needed to quantify the degree of risk these areas face.

FUTURE PLANS: Work on the SPUR2 model for FY94 includes a validation study for the entire suite of models in SPUR2. These models include the basic SPUR2 plant growth model (Hanson et al. 1992), the Colorado Beef Cattle Production Model (Bourdon unpublished), and the FORAGE intake interface model (Baker et al. 1992). This is a cooperative study between the Great Plains Research Unit in Fort Collins, Colorado and the Range Research Unit in Cheyenne, Wyoming. Expected completion data for the validation study is June of 1994.

References

Baker, B.B., R.M. Bourdon, and J.D. Hanson. 1992. *FORAGE:A simulation model of grazing behavior for beef cattle*. Ecol. Mod. 60:257-279.

Baker, B.B., and J.D. Hanson. 1993. *Simulating the effects of climate change on beef cattle production:A methodology for determining simulation sites*. Proc. 46th Annual Meetins, Society Range Management. 46:9-10.

Hanson, J.D., B.B. Baker, and R.M. Bourdon. 1992. *SPUR2 Documentation and Users Guide*. U.S. Department of Agic. Great Plains Systems Research Tech. Report-1. Fort Collins, Colorado. 24 pp.

MODELING THE RAINFALL RUNOFF-PROCESS ON RANGELANDS INCORPORATING SMALL-SCALE SPATIAL VARIABILITY

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ARS-CSU COOPERATIVE AGREEMENT: 58-5402-0-002

PROBLEM: Optimization of plant and animal production from rangelands is dependent on management of the limited water supply in these areas. Grazing intensity has been shown to affect the rainfall runoff process; in general, higher grazing intensities lead to decreased infiltration, which in turn may decrease plant and animal production. This study seeks to characterize the effect of differences in the small-scale spatial variability of factors which control the rainfall-runoff process, caused by differences in grazing intensity, so that optimization of production may be possible. Physical experiments and computer modeling will be used to accomplish this goal.

APPROACH: Small experimental rainfall-runoff plots, approximately 10-feet wide and 30-feet long, will be used to generate physical data for model development and subsequent verification. These plots are located in the Central Plains Experimental Range in areas representative of season-long light, season-long moderate, season-long heavy, and year-long moderate grazing intensities. A rotating-boom rainfall simulator will be used to generate artificial rainfall, and a high-accuracy flume will be used to monitor the hydrograph at the outlet. Physical characteristics of the plots, including microtopography, vegetation density and distribution, soil bulk density, porosity, organic matter, soil moisture, infiltration rates at various tensions, hydraulic conductivity, and wettability, will be measured to a spatial resolution such that the plots are adequately characterized. An attempt will be made to collect data so that spatial averaging is not necessary or limited for the point-scale modeling.

The collected data will be incorporated into computer models capable of such small-scale modeling in order to predict the effects of grazing-intensity induced variability on other rangeland areas. More than one computer model may be developed and/or used. For example, infiltration in three dimensions may be modeled separately to determine if one-dimensional infiltration modeling can be used in combination with two-dimensional overland flow modeling without loss of accuracy. Additionally, these point-scale models will be extended to a larger scale; in doing so, spatial averaging techniques will be tested and/or developed based on the results of the point-scale model(s).

FINDINGS: Data will be collected for this study starting in the spring and summer of 1994. An existing overland flow model capable of incorporating the small-scale spatial variability in data has not yet been identified; therefore, it is likely that one will need to be developed. Due to the expected complexity of the microtopography, the full equations for two-dimensional shallow water flow will have to be used rather than making the common assumptions of either

kinematic wave or diffusion wave. Other researchers have had numerical difficulties developing such a model.

INTERPRETATION: Data interpretations will be presented when data become available.

FUTURE PLANS: A computer model(s) capable of incorporating data collected at a small spatial resolution will be developed and verified using data collected from experimental rainfall-runoff plots. These results will then be extended to larger scales such that optimization of plant and animal production with respect to water management as affected by grazing intensity will be possible. This work is currently in its initial stages, so the approach section contains more details regarding future plans.

DEVELOPING AND EVALUATING SHOOTGRO, A SMALL-GRAIN CEREAL GROWTH AND DEVELOPMENT MODEL

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PROBLEM: Development of small grains has been studied extensively in the past, with major advances made in the 1980s. Indeed, much of our general knowledge of grass development is based on concepts derived from work on wheat and barley. Small-grain development has been shown to be influenced by environmental factors such as water, nutrients, temperature, light, and CO_2, and management practices such as crop rotations, tillage, and residue cover management. Appropriately constructed models should provide a system for testing the effectiveness of alternative management strategies as well as environmental factors. Unfortunately, few existing models predict development accurately enough to allow testing of hypotheses about causes for differential development between management practices, and those models that incorporate environmental factors have not incorporated the leading research of the last couple of decades.

Why emphasize development? Some reasons why small-grain development is important are:

1) Yield is very plastic, with many processes involved in determining final yield. Many of these processes are developmental and phenological, not just physiological.
2) Many management practices need to be timed to specific stages of crop development.
3) The severity of some environmental factors is partly a function of stage of crop development.
4) Crop development can give us "clues" as to how the plant "perceives" its environment.

APPROACH: A group of ARS and university scientists has been established to collaborate on developing a simulation model, called SHOOTGRO, that incorporates the latest research and concepts on small-grain development and physiology. A basic premise is that if SHOOTGRO is to simulate responses to management practices, that the effects of the management practices should be on fundamental factors such as temperature, nutrients, water, and light. In turn, the simulated plant processes must be modeled sufficiently to be able to respond to changes in the fundamental factors resulting from management practices. A simple example can illustrate this point. Different tillage practices (with resulting effects on residue cover) will alter soil temperatures. All current approaches to predicting small-grain phenology use air temperature above the canopy in estimating growing degree-days. Because shoot apex temperature cannot be estimated easily, it would be better to use soil temperature at the crown until jointing, than

air temperature, as an estimate of shoot apex temperature. By using soil temperature, then the effects of tillage practices on phenology can be incorporated, which is not the case when using air temperatures above the canopy.

Studies in the last two decades have resulted in much greater understanding of how shoot and root developmental processes are integrated, along with the integration between plant development and physiology. Fortunately, there have been recent concepts that hold across species, or related species. For grasses, one of these concepts is the role of the phyllochron, or rate of leaf appearance, in understanding the integration, and as a means of marking the time between events or duration of processes. Another concept is that plants consist of the population dynamics of smaller building blocks, called phytomer units. The phyllochron concept is particularly useful in measuring the rate that the phytomer units are added or deleted from the plant.

FINDINGS: In the Approach section it was noted how important the phyllochron concept is in understanding crop development and growth. The SHOOTGRO model uses the phyllochron as a fundamental concept in controlling development and growth. Yet, there are many unresolved questions about the phyllochron and how to use it in models such as SHOOTGRO. To help address these some of the questions, Dr. Wally Wilhelm and myself organized a symposium at the American Society of Agronomy meetings in 1993 entitled "Understanding development and growth in grasses: Role of the phyllochron concept". The purpose was to assemble as many scientists as possible to discuss some of these issues. In addition, several international scientists visited Fort Collins for a couple of weeks to continue the discussion and evaluate how these concepts were incorporated into the SHOOTGRO model. A number of new insights were gained by all, and these are now being incorporated into SHOOTGRO.

One specific finding was based on evaluating the nine published equations to predict the phyllochron of wheat and barley. No equation could adequately predict the phyllochron across a broad range of cultivars, climatic conditions, and management practices. Work has begun on how to improve existing equations.

In 1993, SHOOTGRO was converted from simulating only winter wheat to also simulating spring wheat and spring barley. To test how well the concepts could be extrapolated to different cultivars/species under very different climatic conditions and soils, SHOOTGRO was parameterized for South African cultivars and conditions. Minor adjustments had to be made in certain submodels originally developed for the Northern Hemisphere. The concepts transferred well, and most parameters for spring wheat from North Dakota were very similar for South African spring wheat (which actually are somewhat intermediate between North Dakota spring wheat and winter wheat).

INTERPRETATION: Developmental concepts transfer well among small-grain cereals, and indeed, most grasses. This allows a model such as SHOOTGRO to be modified for differences in morphological form among grasses, and then reparameterized, resulting in a model structure that can simulate different grass species. In addition, crop responses to the environment and

management practices can be predicted, and understanding why the responses occurred explored, helping us to better understand these agricultural production systems.

FUTURE PLANS: Many modifications were made in 1993 to the SHOOTGRO model. SHOOTGRO now needs to be re-evaluated for North American winter wheat, spring wheat and spring barley cultivars and conditions. To incorporate soil management practices better, work on the relationship between soil temperature at crown depth and the phyllochron/growing degree-days relationship is needed. Field experiments are being conducted to develop this relationship. The SHOOTGRO model needs a better soil submodel if responses to management practices is to be satisfactorily simulated. It is believed that the Root Zone Water Quality Model (RZWQM) could provide the needed soil submodel. Initial efforts to integrate SHOOTGRO and RZWQM have begun.

WINTER WHEAT DEVELOPMENT AND GROWTH RESPONSES TO SOIL MANAGEMENT PRACTICES

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CRIS: 5402-61660-004-00D

PROBLEM: Many different soil management practices are available, and promoted for various reasons. In particular, there are many reasons to use no- or low-tillage practices that preserve as much residue cover as possible, especially in dryland wheat production systems. Numerous studies of wheat development and growth have been done, but most have been on responses to fundamental factors such as temperature, water, nutrients, light, and CO_2. These experiments have been conducted in greenhouses, growth chambers, or in the field, with the field studies under more "traditional" agronomic practices (e.g., normal tillage practices). Because wheat is so plastic on how final yield is reached, there is very little understanding how wheat will respond to alternative soil management practices, and equally important, why.

A couple of issues are relevant to our ability to predict and understand plant responses to the environment and management practices. The first is that crop phenological development is primarily controlled by temperature, with secondary factors of light, water, and nutrients. Our current approach to predicting crop phenology uses air temperature above the canopy, with the assumption that air temperature correlates well with shoot apex temperature. In most cases, this relationship works very well. However, in cases such as different tillage practices which alters the residue cover levels, we know that soil temperature is effected. These altered soil temperatures do not always correlate with air temperature above the canopy. Until jointing, which is when the shoot apex rises above the soil surface, using soil temperature at crown depth should give a better estimate of shoot apex temperature. Unfortunately, very little data are available on the relationship between soil temperature at crown depth and crop phenology. Another issue is that the phyllochron, or rate of leaf appearance, is being increasingly used to integrate developmental events and between development and physiology. Yet much remains to be learned about the phyllochron, including what the phyllochron is for many of our cultivars.

APPROACH: We know much about how wheat development and physiology responds to fundamental factors such as temperature, water, nutrients, light, and CO_2. Of course, many questions remain, but my basic premise is that soil management practices are best studied by examining how management practices effect fundamental factors, and then understanding how the plant responds to changes in the fundamental factors. By using simulation models such as SHOOTGRO, which has developmental and physiological processes that respond to these fundamental factors, then prediction of how management practices will affect yield, and why, is possible. This then allows us to extrapolate between study sites, which is a limitation of field studies.

Starting in 1986, a series of experiments has been conducted to examine different management practices. For two years, under conventional tillage practices different irrigation and N fertilizer treatments were tested. Starting in 1991, different tillage practices (conventional tillage and no-till) and residue cover levels (no residue, normal residue, and twice-normal residue) have been tested. Soil and air temperatures, soil water, and soil nutrient levels over time were followed, and subsequent responses in wheat development and growth observed, particularly the phenology and phyllochron.

Because fundamental factors vary considerably over time and spatially, Dr. Fran Pierce is conducting a similar experiment in Michigan. This allows us to expand our measurements over a wider range of conditions (e.g., climate, soils, cultivars).

All of these experiments (and additional growth chamber and greenhouse experiments not mentioned) are intended to address specific hypotheses not addressed by other scientists, or to supplement their work. The data will be used in developing and evaluating the SHOOTGRO model.

FINDINGS: The irrigation work showed that for Great Plains dryland wheat systems, the main yield component is number of spikes per unit area. Water stress at the time of late-jointing is the most critical time controlling spike number by increasing tiller abortion rates.

Preliminary results for the 1992-93 growing season were somewhat different than for the previous year. September and beginning of October 1992 had no rainfall (historically the driest ever recorded), although rainfall during July and August 1992 was above average resulting in significantly above average available water in the soil profile. This was an unusual year where tillage resulted in a dry seed-zone layer that was not replenished during the normal germination period. The result was that the tilled plots had significantly delayed germination, resulting in stand establishment significantly later than in the no-till plots. Significantly greater spatial and temporal variability in emergence also occurred in the tilled plots. Delayed stand established resulted in significantly lower biomass throughout the growing season until maturity in the tilled plots. The yield components are still being analyzed, but preliminary final grain yield results show that the highly significant early biomass differences were not as significantly reflected in final grain yield (see table below). Once again, number of spikes m^{-2} was the main yield component related to final yield.

Tillage Treatment†	Culms	Spikes	Total Spikelets	Fertile Spikelets	Straw Wt	Spike Wt‡
	(#/m^2)	(#/m^2)	(#/spike)	(#/spike)	(g/m^2)	(g/m^2)
No-till	994	680	14.9	12.8	687	757
Tillage	843	614	15.2	13.1	627	744

†All residue treatments pooled within a tillage treatment.
‡Spike weight includes chaff and kernel weight.

INTERPRETATION: In all experiments, plus others not mentioned, the main yield component related to final grain yield is the number of spikes m^{-2}. The main process controlling spike number is tiller abortion, not tiller appearance. Therefore, if only limited irrigation is possible, application at late-jointing is the suggested time, and any management practices increasing soil water at this growth stage is most beneficial for final yield. No-till practices with greater residue cover that tend to preserve soil moisture through the vegetative period tend to reduce tiller abortion over conventional tillage practices with associated lower residue cover.

FUTURE PLANS: This is a long-term experiment that will be continued. In particular we are improving our ability to monitor soil temperatures at the crown depth and relating this to developmental processes (e.g., phyllochron and phenology). This data set needs to be combined with the data that Fran Pierce has also been collecting in Michigan. Several more manuscripts plan to be written on the irrigation and fertilizer experiment.

WINTER WHEAT YIELD AND YIELD COMPONENT RESPONSES TO CROPPING SYSTEMS

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PROBLEM: For a number of decades, the dominant dryland wheat cropping system has been the wheat-fallow rotation, normally with several cultivation passes prior to planting. An advantage of this cropping system is that it is a rather easy system to manage, whereas a major problem is that it is not very economically viable. Economic problems are largely due to the fact that the land is fallow for about 15 out of 24 months, and yields are not very high (Colorado state average is about 33 bu/ac) for dryland conditions. If the cropping system can be changed so that cropping intensity is increased, then the percent time the land is fallow is decreased, and hopefully, economic returns are enhanced. Another benefit of increased cropping intensity is that green biomass is on the land for a greater percent of the time, thus helping to reduce erosion. This is important for land classified as highly erodible and eligibility for government programs.

APPROACH: Research has shown that switching to no-till practices conserves soil moisture, which is the limiting factor in Great Plains dryland agriculture. This small increase in soil water may provide opportunities for trying different cropping systems than wheat-fallow, thus increasing cropping intensity. Yet, the success of alternative cropping systems will be largely a function of the climate and soils of the site. Therefore, different sites along a north-south gradient with similar rainfall but increasing potential ET southward have been established. Treatments at each site (Sterling, Stratton, and Walsh) were situated across a catena of different soils. All treatments use no-till practices. The rotations are wheat-fallow, wheat-corn-fallow, and wheat-corn-millet-fallow.

The experiment was started in 1985, but by 1990 the question arose of why the observed yields were obtained. My involvement is trying to understand why wheat responds as it does to the different treatments. The starting point was to collect four years of data on wheat yield and yield components. Then, if sufficient resources become available, to pursue the question in more detail.

FINDINGS: Wheat yields were not reduced by switching to cropping systems with greater cropping intensity. As in other studies for the Great Plains, the main yield component is number of spikes m^{-2}.

INTERPRETATION: My current hypothesis is that spike number is primarily controlled by tiller abortion rates, and secondarily by tiller appearance rates. Under cropping systems with greater cropping intensity, winter wheat is able to maintain or increase its grain yield by reducing tiller abortion rates, thereby increasing spike number.

FUTURE PLANS: Perhaps a fifth year of data will be collected in 1994, particularly since the data can be used in our modeling efforts such as SHOOTGRO and RZWQM. If resources can be obtained, it would be very useful to measure a few variables, such as the rate of leaf appearance and culm density over time. Currently there are no measurements on wheat being taken during the growing season.

ESTIMATING FALL WINTER WHEAT BIOMASS PRODUCTION TO ASSIST SCS WITH DETERMINING COMPLIANCE FOR GOVERNMENT PROGRAMS

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CRIS: 5402-66000-001-00D

PROBLEM: Eastern Colorado is classified as highly erodible land (wind erosion). If wheat producers want to be involved in, and eligible for, government programs, then they must take actions to reduce the erodibility of their land. One of the main actions possible is to maintain a specified minimal level of residue cover, especially during periods of maximum erodibility. The SCS considers green biomass as contributing to the total residue cover. However, SCS has had to guess how much wheat biomass would accumulate during the fall for different locations, planting dates, climatic conditions, soils, and so forth. Validating these guesses are made more difficult by the scarcity of biomass estimates of winter wheat during the fall. SCS has requested assistance in developing a more objective and defendable method of estimating the amount of biomass expected when winter starts.

APPROACH: The SHOOTGRO model is being used to estimate the minimum biomass expected 90% of the time on 1 December. Locations in eastern Colorado were identified (e.g., Akron, Sterling, Leroy, Stratton, Walsh) with have long-term weather records (> 50 years). Different initial conditions (e.g., planting date, planting density, soil water and N availability, major soil type) are being tested at each location across the complete weather data set. The minimum biomass simulated on 1 December 90% of the time will be noted, and relationships with the initial conditions will be developed.

FINDINGS: The first step was to convert the weather files from NOAA form to a form needed by SHOOTGRO. This also involved estimating missing data. The SHOOTGRO model was modified to output the appropriate values on 1 December. Predicted biomass at 1 December is now being compared to observed biomass as validation of SHOOTGRO for this application.

FUTURE PLANS: At least 20,000 simulation runs are required for this project. The simulation runs are being done, then the output data will be analyzed. Project products will include a report to the SCS and publication in a professional journal.

SPATIAL ANALYSIS OF HYDRAULIC AND PEDOGENIC IMPACTS ON CROP PRODUCTIVITY

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CRIS: 5402-13610-003-00D

PROBLEM: Analysis of field experimental treatment effects is confounded by non-random distribution of fundamental soil properties, such as horizonation, texture, hydraulic and biochemical characteristics. Field investigations demonstrate that fluxes of energy and vapor are spatially variable and that crop yield is correlated with variation in soil hydraulic properties. Scaling point-based simulation models to field or regional applications requires conceptual and methodological advances. Knowledge of spatial effects on dynamic processes can guide experimental and field plot design, as well as interpretation of soil and crop response to experimental treatments. Field investigations should provide baseline data on soil textural, hydraulic, and pedogenic properties; test the uniformity and homogeneity of distribution of these properties; and evaluate surface temperature measure as reliable indicators of biologically significant soil properties.

APPROACH: A dryland spring wheat crop, established in 1993, served as bio-indicator for non-uniform distributions of soil water and nutrient supply. The spatial distribution of soil hydraulic and pedogenic properties, crop stand characteristics, and indices of soil and canopy energy flux were quantified over a 1.8 ha field site using a 30 m or 10 m grid. The joint distribution of these parameters will be subjected to factor, cluster and correlation analysis to identify structural features of their spatial distribution. Relations among hydrologic, pedogenic and crop growth indices will be tested and quantified using regression and geostatistical techniques.

FINDINGS: Above-ground crop biomass varied from 230 to 700 g/m^2, with a significant systematic spatial pattern. Temperatures of pre-till soil surface and mature canopy (incomplete closure) were positively intercorrelated, and positively correlated with pre-season water stored below 1.2 m, but negatively correlated with canopy height and biomass at harvest. Canopy height and biomass were negatively correlated with pre-season water stored below 1.2 m. Canopy height, at harvest was positively correlated with pre-season water stored in the 0.6 to 0.9 m soil layers. These preliminary analyses suggest structural differences in the distribution of pre-season recharge of soil water results from hydrologic/pedogenic processes that modify subsequent crop productivity and can be detected by strategic surface temperature measures.

FUTURE PLANS: Hydraulic and chemical analysis of soil samples, and further sample and data processing are required prior to complete data analysis. Structured hypotheses will be assessed by factor, cluster, and correlation analysis of experimental data. These hypotheses will test the general hypothesis that the spatial structure of soil hydrologic and pedogenic properties

constrains crop productivity, and can be detected with low-cost remote sensing techniques. Further quantification of *in situ* hydraulic properties, surface temperatures and productivity of a spring barley crop may be warranted in the 1994 growing season. Formal archives of baseline data will be established. These data will support recommendations for experimental designs, e.g. nearest neighbor analysis, adjusting plot response for systematic trends in biologically significant soil properties. These data will be available to test scaling theory capable of predicting impacts of soil hydraulic/pedogenic processes on crop productivity.

SPATIAL AND TEMPORAL VARIABILITY OF SOURCES, SINKS, SURFACE, AND SUB-SURFACE FLUXES OF SOIL GASES USING PROCESS-BASED MODELING

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PROBLEM: Changes in the climate pattern, crop production and management strategies can totally alter the existing above- and below-ground environment, ecosystem structure, and composition. Changes in the biological, chemical, and physical composition of the soil can have direct effects on the carbon (C) and nitrogen (N) cycling processes, and the surface/sub-surface evolution and phasic (aqueous and gaseous) transport of soil gases (e.g. CO_2, CH_4, and N_2O). The development of a soil gas exchange model, integrated with process-based models simulating the dynamics of the biological and chemical soil processes, and water and heat flow, can provide detailed understanding and quantitative assessment of the dynamics of the C and N balance in the soil, and fluxes of greenhouse gases.

APPROACH: A one-dimensional finite difference model was developed to simulate advective-dispersive and diffusive transport of the dissolved and gaseous forms of CH_4, CO_2, N_2O, and O_2 in the soil. Mass transport of the gas species was primarily defined by the flux of soil water. Movement of water and heat in the soil and profile distributions of soil moisture content and temperature under saturated, partially saturated, and/or unsaturated soil conditions were determined by linking the gas transport routine to a water and heat flow (CHAIN-2D) model. The CHAIN-2D model simulates soil water flow by numerically solving the modified Richard's equation that includes a sink term due to water uptake by plant roots. Soil heat transport was governed by conduction and convection with the flowing water.

The dynamic concentrations of aqueous CH_4, CO_2, N_2O, and O_2 at different layers in the soil were determined from a direct interaction between the soil gas, heat, and water transport routines with the root growth, soil chemistry, and nutrient cycling submodels. Root growth and extension was driven by the C and N supply to the plants, soil O_2 and water concentrations, soil temperature, and soil compaction. Root respiration, root rub-off, senescence, and C exudation, and uptake of O_2 and NO_3^- were considered in the root submodel as processes directly determining the temporal and spatial distributions of C and N substrates, O_2 and CO_2 gases in the soil. Process rate equations describing the C and N transformations, from various types of soil organic residues under limiting and non-limiting soil O_2 conditions, were used to estimate the concentrations of the various components of the C and N balance equations. These equations includes microbe-mediated processes sensitive to the spatial and temporal variations in soil moisture, temperature, concentrations of O_2, CO_2, C, and N substrates. A bicarbonate buffering system was included, in addition to Henry's Law, to quantify the equilibrium concentration of CO_2 in the aqueous and gaseous phases, and assess soil pH.

The input parameters, initial soil, and atmosphere boundary conditions for the simulation runs, including field data for model validations, were taken from a shortgrass steppe dominated by blue grama grass [Bouteloua gracilis (H.B.K. Lag)] and a tillage-residue wheat (Triticum aestivum L. emThell) experiment conducted in 1992. The physical and chemical properties of the specific soil horizons in both sites were considered to determine the effects of soil layering. Profile measurements of soil moisture, soil temperature, and soil concentrations of CH_4 and CO_2 were taken during the course of these experiments.

FINDINGS: The initial simulations were made to compare fluxes of soil gases in isothermal and non-isothermal conditions. With no sources and sinks for the gases included in the simulation period, the aqueous concentration of the soil gases at different soil layers were determined by water movement and the temperature-dependent solubility of the gases in water. Under non-isothermal conditions, the gas concentrations in the aqueous phase were observed to be a linear function of soil temperature. Under isothermal conditions, gas movement between soil layers was primarily driven by water movement and gas concentration gradients between layers.

With sources and sinks included, the gas concentration at different soil depths was determined by the gas species, presence/absence of roots, pH, O_2 concentration, the concentration and type of C and N substrates in the soil. Different gas species have different solubility properties in water and their consumption/production is determined by processes dependent on O_2 concentration. Where roots are present, O_2 is consumed and CO_2 is produced by root respiration; the magnitude of consumption and/or production was determined by the C and N supply to the plant and soil moisture. Because the root uptake rate of O_2 is higher than the replenishment rate of aqueous O_2 in the soil, the level of consumption of O_2 and activities (growth, extension, and respiration) of roots were critically dependent on the length of time the soil remains saturated. The level of soil water and duration of water saturation were also critical in determining the microbe-mediated organic matter decomposition, and CO_2 production. CO_2, in the aqueous phase, undergo chemical (CO_3-HCO_3^- equilibrium system) reactions, determine soil pH, and can escape in the form of a gas into the soil air.

A CH_4 consumption and/or production submodel was developed to quantify the sources and sinks of CH_4 in the soil. Under aerobic conditions, CH_4 was produced by oxidation; however, the rate of CH_4 uptake was much higher than CH_4 evolution. With the typical porous property of the sandy loam soils at the shortgrass steppe, anaerobic conditions were almost non-existent, except immediately following a large precipitation event when surge in CH_4 evolution was obtained from the simulation runs. Field data taken from a wetting-drying cycle confirm these results.

FUTURE PLANS: Model validation and testing will be accelerated with emphasis on the use of existing soil gas data. We will be evaluating the 1- and 2-dimensional models initially for use in RZWQM, NTRM-2D, and other comprehensive process models we have in progress.

Interfaces will be developed with RZWQM model. The field data collection program will be reactivated to collect necessary detailed information from typical agricultural management systems under corn and wheat. Close collaboration will be maintained with other on-going soil gas research.

WATER FLOW PATTERNS AND CHEMICAL LEACHING IN EVERY FURROW AND ALTERNATE FURROW IRRIGATION SYSTEMS

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CRIS: 5402-13660-002-00D

PROBLEM: Furrow irrigation is commonly used in arid, semi-arid, and sub-humid regions to apply supplemental water to row crops. Deep percolation losses of water generally occur with furrow irrigation because, to apply sufficient water to replenish the root zone of the soil farthest from the source, over-irrigation occurs near the source. Water is usually applied to each furrow in the field but some researchers have proposed irrigating alternate furrows instead of every furrow in a field to increase water use efficiency. Field research has shown that irrigation water use decreased by 30% to 50% with alternate furrow irrigation compared with every furrow irrigation. Better knowledge of two-dimensional water infiltration and water holding capacities for different soil types would help minimize overirrigation yet provide optimum water supplies to the crop. The presence of chemicals and fertilizers in groundwater supplies is a concern in agricultural regions in the United States. Contamination of groundwater with mobile chemicals such as nitrate is attributed to deep percolation of water containing the chemical. The amount of chemical in groundwater can be partly controlled by management of water application to limit deep percolation. If deep percolation of water is inevitable, such as in part of a field under furrow irrigation, another alternative is to isolate the chemical from the drainage water. Lysimeter studies showed that $CaCl_2$ pellets placed in a band in the row at the same level as or higher than the level of water in the furrow required more water for leaching than if the $CaCl_2$ was placed below the water level in the furrow.

APPROACH: Models can be used as convenient tools for the study of water and chemical movement in irregular, heterogeneous soils. We evaluated the SWMS_2D finite element model as a means to study water and chemical movement in ridged, furrow-irrigated soils and found acceptable agreement between laboratory measurements and model results. We then used the model to investigate water and chemical movement in every furrow and alternate furrow irrigation systems for two soils, a loamy sand and a clay loam. Chemical bands were placed either in the ridge or in the furrows for both irrigation systems.

FINDINGS: Both furrow irrigation systems resulted in water isolation zones in which the water in these zones contributed little to the overall drainage from the profile. The soil water contents after infiltration and redistribution were more uniform for the every furrow irrigation than for the alternate furrow irrigation for both soils. The water distribution was more uniform with alternate furrow irrigation in the finer textured soil than in the coarser soil. Chemical movement occurred least with the alternate furrow irrigation and chemical placed under the non-irrigated furrow. The greatest chemical leaching was predicted with furrow placement of chemical and every furrow irrigation. Chemicals placed under the non-irrigated furrow in the

loamy sand may not be available for plant uptake because the soil remained dry. With either form of furrow irrigation placement of a fertilizer in the ridge rather than in the furrow would decrease leaching of the fertilizer and keep the fertilizer in the root zone.

INTERPRETATION: Chemical movement from the root zone can be partly controlled by better knowledge of two-dimensional water infiltration and water holding capacities for different soil types and the development of better irrigation management practices to help minimize overirrigation yet provide optimum water supplies to the crop. A promising irrigation management system identified in this study is alternate furrow irrigation with chemical placed in the ridge.

FUTURE PLANS: A field study is planned for 1994 in cooperation with Lynn Porter and Harold Duke to study alternate furrow irrigation and band nitrogen placement. Specific objectives for the study include: 1. Determine the recharge of plant available water with every furrow and alternate furrow irrigation systems; 2. Determine nitrate leaching patterns from band application of nitrogen fertilizer in every furrow and alternate furrow irrigation systems; and 3. Provide a data base of water and nitrate movement to further calibrate and test the SWMS_2D model.

ROOT ZONE WATER AND CHEMICAL TRANSPORT AS AFFECTED BY ROOT WATER UPTAKE

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CRIS: 5402-13660-003-00D

PROBLEM: The work done by soil physicists over the last few decades has deepened our understanding of the basic theory of water and chemical movement in soil. However, not enough has been done to fully understand the effects of soil management on the control of chemical movement through and out of the root zone. The advent of mechanistic, two-dimensional models of soil water, heat and chemical movement now allows in-depth study of management effects on the soil environment. The effects of the crop plant on the movement of chemicals have largely been ignored. The major thrust of this work will be to develop an understanding of soil management effects on the soil environment and how changes in the soil environment affect the growth of the corn root system. Special emphasis will be placed on how root density differences between row and interrow positions, with the concurrent uptake of water and chemical by the plant, affect the potential leaching of common agrichemicals and fertilizers into groundwater supplies.

APPROACH: The ROOTGROW model of two-dimensional corn root growth was developed and linked with the SWMS_2S model of soil temperature, water content and chemical concentration. The model then grows roots into the soil based on the soil environment and the phenological development of the plant. The plant root system, in return, affects the soil environment through water and chemical uptake by the plant.

FINDINGS: Testing has shown that the model will adequately reproduce root density distributions as found in the literature. Root growth predicted by the model is responsive to changes in the soil environment, especially to bulk density and temperature changes. Water content distributions show a drier zone directly beneath the plant because of water uptake by the root system. Subsurface water flow paths show water moving from wetter zones that do not contain roots to the drier zone containing roots. Mobile chemicals in the water also move towards the root zone and imply that chemical leaching out of the root zone may be modified by the placement of the chemical near the crop plant in the row instead of in the interrow zone.

FUTURE PLANS: We will use the model for the study of soil management effects on root system development, of climatic conditions on root water uptake, and of root water uptake on subsurface water and chemical transport. The model will also be used to study the effects of root density distribution on recharge of plant available water under rainfall and irrigation. Our aim is to identify promising soil and crop management systems to maximize water use efficiency by the crop and to minimize leaching of chemicals to the groundwater.

A field study is planned for 1994 in cooperation with Lynn Porter and Harold Duke to study alternate furrow irrigation and band nitrogen placement. Specific objectives for the study include: 1. Determine the recharge of plant available water with every furrow and alternate furrow irrigation systems; 2. Determine fertilizer nitrogen uptake from bands of fertilizer placed either in the row or in the furrow with every furrow and alternate furrow irrigation systems; 3. Determine nitrate leaching patterns from band application of nitrogen fertilizer in every furrow and alternate furrow irrigation systems; and 4. Provide a data base of water and nitrate movement for calibration and testing of the two-dimensional soil and root growth model.

CLIMATE CHARACTERIZATION FOR AGRICULTURAL PURPOSES

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CRIS: 5402-13610-003-00D

PROBLEM: Several research projects have as a collateral problem the characterization of climate and weather. These projects include "Estimating Fall/Winter Wheat Biomass as Soil Cover" in cooperation with Travis James, Soil Conservation Service, and "Modeling Dryland Crop Production" in cooperation with G. Peterson and D. Westfall, Colorado State University.

APPROACH: Available weather data are acquired and analyzed for various purposes, including:

- to provide input data (driving variables) for simulation models including SHOOT-GRO and RZWQM;
- to provide better understanding of field physical processes in studies to determine best management practices. Weather plays an important part in plant establishment, survival, and yield.

FINDINGS: Data from Sterling, Stratton, Walsh, Leroy, and Akron (all in Colorado) have been located, and initial analyses begun. The published Weather Service data for Leroy, from the 1940's to present, was found to be complemented by an existing handwritten record back to the 1890's. Increasinging the record length yields important statistical power. The early data were acquired in cooperation with the Colorado Climate Center. We computerized this entire record, and have begun a preliminary analysis of daily, monthly, and annual rainfall frequencies.

FUTURE PLANS: Now computerized, the early Leroy record is being converted to National Weather Service format. Further statistical work will be done with Sterling, Stratton, Walsh, and Akron data, to complete the climate characterizations desired by both the Peterson/Westfall team and by the Soil Conservation Service State Office (see McMaster project description).

QUANTIFYING CROP RESIDUE ARCHITECTURE AND REGULATION OF HEAT AND VAPOR FLUX

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CRIS: 5402-13610-003-00D

PROBLEM: Develop and implement a physically-based thermal module that simulates continuous thermal and water vapor dynamics in soil-residue-plant-atmosphere agroecosystems, using input and system parameters required by the Root Zone Water Quality Model (RZWQM). The module should build on existing theory and observations to provide original results that fill knowledge gaps. Knowledge of soil thermal profiles will also enhance simulation of biological processes such as plant phenologic development and biogeochemical transformations. Simulation accuracy, including precision and bias, should be specified for bounded input and satisfy criterion established by RZWQM modules simulating plant development and biogeochemical transformations. Findings should be submitted for peer-review publication.

APPROACH: Simultaneous heat and water (SHAW) transport in the soil-plant-atmosphere continuum is simulated using numerical techniques to solve the continuity equations for heat and water flow. Components of the SHAW model were incorporated into RZWQM as user-selected modules to enhance partition of soil heat flux to multiple sinks including snow-melt, freeze-thaw, and soil warming. Canopy and residue architectures are explicit components of SHAW and the Shuttleworth-Wallace module currently used in RZWQM.

FINDINGS: Derivation of Penman form of the surface energy balance equation provided *a priori* quantification of soil heat flux. This parameter is required to quantify hourly evapotranspiration using the Shuttleworth-Wallace of RZWQM and the soil heat partitioning module of SHAW. Sensitivity analysis indicates simulation uncertainty is shifted from radiative to aerodynamic effects of residue architecture when a gradient form of the surface energy balance equation is substituted for a Penman form. Modular implementation of alternative energy balance equations enables user-selection, but requires structured analysis and specification of system and sub-system boundary conditions.

FUTURE PLANS: Complete implementation of SHAW modules into RZWQM requires further verification of one-to-one correspondence with the original SHAW simulation. Comparative analysis of SHAW and Shuttleworth-Wallace modules will be structured by common scenario analysis to evaluate radiative, aerodynamic, heat and vapor transport processes. These comparisons will evaluate relative sensitivity to input errors, and trade-offs of computational ease and accuracy losses associated with model simplification. Specification of system and boundary condition sensitivities will precede field evaluation of module performance.

QUANTIFYING AERODYNAMIC RESISTANCES AND ENERGY EXCHANGE WITHIN CROP RESIDUES

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CRIS: 5402-13610-003-00D, GPSR
5407-12130-002-00D, CGPR

PROBLEM: Quantification of soil, water and heat transport is constrained by incomplete knowledge of aerodynamic resistances within the residue sub-layer. Critical knowledge gaps include quantifying effects of residue architecture on short-wave reflectivity and aerodynamic resistances. A silhouette factor relating wind speed profile characteristics to crop residue dimensions can be used to quantify wind speed profiles and soil erosion potential for alternative residue management practices. Reducing these knowledge gaps will enhance simulation of soil and water management effects provided by the Root Zone Water Quality Model. Field validation of this model can also extend knowledge of residue effects on heat and water transport.

APPROACH: Dryland wheat, cultivated under no-till or conventional tillage at the CSU Horticulture Farm, was harvested to obtain 0.2 m stubble heights. Dryland sunflower, at three populations, cultivated at the CGPR site near Akron, CO, was harvested to obtain 0.3 or 0.7 m stubble heights. Arrays of anemometers and fine-wire thermocouples were installed at 0.05 m, 0.5 m, 2.0 m, and 90% of the stubble heights to quantify wind speed and thermal profiles. A needle anemometer was evaluated for near-surface wind speeds. Components of the soil energy balance were quantified by net radiometers, pyranometers, soil heat flux plates and soil thermocouples. Soil water contents were determined by time domain reflectometry at 0.1, and 0.2 m depth intervals. Standard micrometeorological procedures were used to quantify sensible heat flux and effective aerodynamic resistance within the residue sub-layer. Wind profile stability and silhouette factor theory will be used to determine relationships among aerodynamic resistances, residue architectures and wind speeds.

FINDINGS: Sunflower and vertical wheat residues introduced similar aerodynamic drag factors, though differing in architecture, reducing near-surface wind speeds to 20% of reference speeds (2 m). The horizontal architecture of old wheat residues offered limited aerodynamic drag, with near-surface wind speeds 50% of that observed at the reference height. Surface warming was enhanced under vertical residue architecture, relative to flat residues. Reduced turbulent mixing within the vertical residue sub-layer tended to 'insulate' the soil surface from cooler ambient mid-day temperatures. The single-needle anemometer sensor signal output was highly correlated with wind speed determined by a cup anemometer, using appropriate data transformations. Sensitivity analysis indicated sensor sensitivity declined for wind speeds exceeding 1.5 m s^{-1}. Partitioning of incoming radiation to energy balance components was altered by residue architecture. Reflected short-wave radiation was reduced for new residues,

attributed to back-scattering among vertical residue elements. Outgoing long-wave radiation was higher for older horizontal residues, due to elevated residue temperatures.

FUTURE PLANS: Quantification of wind speed and thermal profiles, and energy balance components will continue at the GPSR site through August, 1994 and at the CGPR site through May, 1994. Data processing and analysis will support manuscript preparation and submission for peer-review publication. Archived data will also enable field validation of residue effects on energy exchange processes simulated by RZWQM v 2.2, under development at GPSR.

REGIONAL ANALYSIS OF CONTROLS ON SOIL CARBON LEVELS

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CRIS: 5402-11000-002-01S

PROBLEM: Models of soil organic matter dynamics are being used to support research and management of cropping systems and to evaluate interactions between agriculture and climate change as they affect greenhouse gas emissions and the global C balance. A new version (4.0) of the Century model has been developed to facilitate simulation of complex cropping systems. To rigorously analyze the effects of management practices and climate on soil C dynamics, the model must be applied to a variety of cropping systems under varying climate and soil conditions. A thorough multi-site validation is needed to assess limitations and uncertainties in applying the model for local and regional applications.

APPROACH: A modeling database is being assembled from benchmark data (obtained with funding from EPA) from 39 long-term field experiments in the U.S. and Canada. The data include records of climate, crop productivity, soil organic matter change and management histories across a range of soil types and climate zones. A total of 208 site-treatment combinations are represented, including different crop rotations, tillage and fertility treatments and comparisons with native vegetation. Data are being organized to provide the necessary initialization of site-specific model parameters (eg. soil texture), management sequences (eg. crop types, fertilizer application schedules), driving variables (eg. temperature, precipitation) and validatation data (eg. time series of crop production and soil C and N contents) for simulations of historical changes in soil C. In addition to evaluations of historical changes, we are simulating present management systems under climate change scenarios involving increased temperature and/or increased CO_2.

FINDINGS: Information for 18 of the long-term sites have been incorporated into the modeling database to date. Initial model applications were conducted on long-term experiments in the northern Great Plains, at Indian Head, Swift Current and Melfort, Saskatchewan, representing the most climatically extreme sites in the network. Crop rotations (wheat-fallow vs continuous wheat) and fertility (N+P vs only P) treatments were simulated. Simulation of historical trends (ca. 1880-present) correctly ranked treatment effects on soil C and, using measured initial C levels (1950's), deviations of simulated vs measured C were < 10%. Mean crop productivity was correctly ranked by treatment but tended to be underestimated for wheat-fallow treatments at the drier sites, Indian Head and Swift Current -- consequently, we are performing further analyses of the drought response function. For Indian Head and Swift Current, four climate change scenarios (1990-2040) were run assuming: i) present climate and CO_2, ii) increasing temperature (0.01°C/year), iii) increasing CO_2 (700 ppm by 2040), and iv) increasing temperature and CO_2. Both CO_2 scenarios resulted in increased soil C levels due to higher productivity and crop residues. However, management related differences overrode

climate change effects. Under all scenarios, fallow-wheat-wheat rotations resulted in declining C levels during the projection period while continuous wheat rotations accumulated soil C.

INTERPRETATION: The model (Century version 4.0) can reasonably predict soil C dynamics in management systems for climate zones and soil types outside the conditions of its original parameterization. More analysis is needed to evaluate the generality of functions for crop production response to stress (eg. drought). For the sites analyzed so far, the model suggests climate change impacts on soil C are subordinate to management effects.

FUTURE PLANS: Model database compilation of the remaining sites will be completed by April/May 1993. We will continue baseline (historical period) model analyses for an additional 12-15 sites representing principle climate and soil zones and management systems, followed by analyses of potential climate change effects for these sites.

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Publications

Aiken, R., Flerchinger, G., Nielsen, D., Alonso, C., and Rojas, K. 1993. Instrumented measure and simulated solutions for the soil energy balance under residues. Agronomy Abstracts 85:8.

Ahuja, L.R., DeCoursey, D.G., Hanson, J.D., Nash, R.G., Rojas, K.W. and Shaffer, M.J. 1993. Integrated system modeling of the effects of management under different conditions: A root zone water quality model (RZWQM). Federal Interagency Meeting on Hydrologic Modeling Demands for the 90's. (Invited)

Ahuja, L.R., DeCoursey, D.G., Barnes, B.B. and Rojas, K.W. 1993. Characteristics of macropore transport studied with the ARS Root Zone Water Quality Model. ASAE Trans. 36:369-380.

Ahuja, L.R., Wendroth, O. and Nielsen, D.R. 1993. Relation between initial drainage of surface soil and average profile saturated conductivity. Soil Sci. Soc. Am. J. 57:19-25

Anderson, G.L., Hanson, J.D. and Haas, R.H. 1993. Evaluating Landsat thematic mapper derived vegetation indices for estimating above ground biomass on semiarid rangelands. Remote Sensing and the Environment 45:165-175.

Baker, B.B., Hanson, J.D. and Bourdon, R.M. 1993. Analysis of the potential effects of climate change on rangeland production and utilization. International Grassland Congress.

Baker, B.B., Hanson, J.D., Bourdon, R.M. and Eckert, J.B. 1993. Analysis of the potential effects of climate change on rangeland ecosystems. Climate Change 25:97-117.

Ball, D.A., and Shaffer, M.J. 1993. Simulating resource competition in multispecies agricultural communities. Weed Research:33:299-310.

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1993. NLEAP Western Database, Version 1.2. Soil Science Society of America, Madison, WI.

Benjamin, J.G. 1993. Tillage effects on near-surface soil hydraulic properties. Soil Till. Resea. 26:277-288.

Benjamin, J.G., Havis, H.R., Alonso, C.V. and Ahuja, L.R. 1993. Modelling water and chemical movement in every furrow and alternate furrow irrigation systems. Agron. Abst. pp. 341.

Buchleiter, G.W., Farahani, H.J., Ahuja, L.R., Duke, H.R. and Heermann, D.F. Model evaluation of ground water contamination under center pivot irrigated corn in eastern Colorado. The International Symposium on Water Quality Modeling, sponsored by the American Society of Agricultural Engineers. Hyatt Orlando, Kissimmee, Florida, April 2-5, 1995.

Cole, C.V., Paustian, K., Elliott, E.T., Metherell, A.K., Ojima D.S. and Parton, W.H. 1993. Analysis of agroecosystem carbon pools. Water, Air and Soil Pollution, 70:357-371.

Elliott, E.T., Paustian, K., Collins, H.P., Burke, I.C., Monz C.A. and Frey, S.D. 1993. Management impacts on C pools and dynamics in soils of the Central U.S. region. Bulletin of the Ecological Society of America, Supplement to vol 2., p.225 (abstract)

Ferreira, V.A. and Lauenroth, W.K. 1993. Computer Simulation Modeling of Pesticide Fate. In Jack Altman (ed.), Pesticide Interactions in Crop Production, CRC Press, p. 87-111.

Foy, J.K, Hanson, J.D., Parton, W.J. and Kelly, E.F. 1993. Soil organic matter changes as a function of stocking rate and grazing system. Abstracts of Papers for the 45th Annual Meeting of the Society for Range Management.

Hanson, J.D. and Baker, B.B. 1993. Simulating the effects of climate change on beef cattle production: a methodology for determining simulation sites. Abstracts of Papers for the 45th Annual Meeting of the Society for Range Management. (invited).

Hanson, J.D. and Baker, B.B. 1993. Chapter 29. Simulation of Rangeland Production: Future Applications in Systems Ecology. Pages 305-313 in: Michael F. Goodchild, Bradley O. Parks, and Louis T. Steyaert (eds.), Geographic Information Systems and Environmental Modeling. Oxford University Press. (Invited).

Hanson, J.D., Baker, B.B. and Bourdon, R.M. 1993. Comparison of the effects of different climate change scenarios on rangeland livestock production. Agricultural systems 41:487-502.

Harrell, D.M., Wilhelm, W.W. and McMaster, G.S. 1993. SCALES: A computer program to convert among three developmental stage scales for wheat. Agron. J. 85:758-763.

Hart, R.H. and Hanson, J.D. 1993. Managing for economic and ecological stability of range and range-improved grassland systems with the SPUR II model and the STEERISKIER spreadsheet. International Grassland Congress (invited).

Ma, Q.L., Ahuja, L.R., Rojas, K.W., Shaffer, M.J., Hanson, J.D., Boesten, J.T.I., McMaster, G.S. and Ferreira, V.A. 1993. Integrated-systems modeling of the effects of management on water quality: The Root Zone Water Quality Model (RZWQM). In Proceedings of the Conference on Agricultural Research to Protect Water Quality. pp. 367-369.

Ma, Q.L., Ahuja, L.R., Rojas, K.W. and DeCoursey, D.G. 1993. Integrated-systems modeling of the effects of management on water quality. In Proceedings of the Conference on Agricultural Research to Protect Water Quality. Feb. 21-24, Minneapolis, MN.

McMaster, G.S. and Wilhelm, W.W. 1993. Comparison of equations for predicting the phyllochron of grasses. Amer. Soc. Agronomy Abstracts, p. 118. (Invited paper.)

Nokes, S.E., Hanson, J.D., Jones, J.W. and Workman, S.R. 1993. Investigation of the plant growth and water uptake algorithms used in water quality models: A literature review. Agricultural Research to Protect Water Quality. (Invited)

Paustian, K., Elliott, E.T., Collins, H.P., Cole, C.V. and Paul, E.A. 1993. Changes in active C fractions as a function of land management practices. Agronomy Abstracts, p. 257.

Rawls, W.J., Ahuja, L.R., Brakensiek, D.L. and Shirmohammudi, A. 1993. Infiltration and soil water movement. Handbook of Hydrology: 5.1-5.51.

Rojas, K.W., Ahuja, L.R., Ma, Q.L., DeCoursey, D.G., Ferreira, V., Hanson, J.D. and Shaffer, M.J. 1993. Using RZWQM to model management effects on water quality. Proc. Fed. Interagency Workshop Hydrol. Modeling Demands for the 90s. USGS Water Resour. Rep. 93-4018: 5.1-5.7.

Shaffer, M.J. and Brodahl, M.K. 1993. The NLEAP model as a teaching tool. 1993 Agronomy Abstracts. American Society of Agronomy, Madison, WI. p. 24.

Shaffer, M.J., Brodahl, M.K. and Wylie, B.K. 1993. Integration and use of the Nitrate Leaching and Economic Analysis Package (NLEAP) in the GIS environment. Proceedings of the Federal Interagency Workshop on Hydrologic Modeling Demands for the 90's. June 6-9, 1993, Fort Collins, CO. pp 5-28 to 5-35.

Shaffer, M.J., Hanson, J.D., McMaster, G.S., Ahuja, L.R. and Buchleiter, G.W. 1993. Great Plains Framework for Agricultural Resource Management (GPFARM). GPSR Technical Report No. 5. USDA-ARS, Great Plains Systems Research Unit, Fort Collins, CO. 14 pp.

Shaffer, M.J., Hanson, J.D., Baker, B.B., Bartling, P.N.S., Edmunds, D. and Brodahl, M.K. 1993. GPFARM: A Decision Support System for Water and Nutrient Management in Great Plains Agriculture. 1993 Agonomy Abstracts. American Society of Agonomy, Madison, WI. p. 73.

Shaffer, M.J. and Wylie, B.K. 1993. Using the NLEAP model and GIS to integrate regional soils, aquifer, climate, and management data in eastern Colorado. Agricultural Research to Protect Water Quality. Proceedings of the Conference, February 21-24, 1993, Minneapolis, MN. Soil and Water Conservation Society, Ankeny, IA. pp. 365-366.

Wilhelm, W.W. and McMaster, G.S. 1993. The importance of the phyllochron in studying development and growth of grasses. Amer. Soc. Agronomy Abstracts, p. 127. (Invited paper.)

Wilhelm, W.W., McMaster, G.S. Rickman, R.W. and Klepper, B. 1993. Above ground vegetative development and growth of winter wheat as influenced by nitrogen and water availability. Ecol. Model. 68:183-203.

Williams, R.D. and Ahuja, L.R. 1993. Using a one-parameter model to estimate the soil water characteristic. Adv. Hydro-Sci. 1:485-490.

RANGELAND RESOURCES RESEARCH UNIT

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MISSION STATEMENT

To develop an understanding of the interrelations of the basic resources that comprise rangeland ecosystems. Research is directed toward the development of science and technology that contributes to enhanced forage and livestock production and sustainable, productive rangelands in the Central Great Plains.

TECHNOLOGY TRANSFER - 1993

Rangeland Resources Research Unit

Unit sponsored and participated in a workshop "Rangelands - It's Management and Use" and High Plains Grasslands Research Station field day that highlighted research program. The workshop and field day involved a total attendance of about 260 producers, researchers, land managers and general public.

HART, RICHARD --

February: Attended XVII International Grassland Congress, New Zealand & Australia; presented invited paper "Managing for economic and ecological stability of range and range-improved grassland systems with the SPUR II model and the STEERISKIER spreadsheet", co-authored by J. D. Hanson.
April: Delivered lecture and gave station tour to RS 472, "Range Ecosystem Planning," CSU. Reviewed grazing research and presented seminar for Agronomy Dept., Auburn University, Auburn, AL.
May: Prepared history of HPGRS; printed for 65th Anniversary Open House Delivered lecture and gave station tour to RgMg 4350, "Field Application of Range Management Techniques," UW.
June: Participated in 65th Anniversary Open House of HPGRS.
August: Delivered H. Wayne Pritchard Memorial Lecture, "Exploring conservation frontiers: a perspective by Theodore Roosevelt," at annual meeting of Soil & Water Conservation Society, Ft. Worth, TX.
November: Attended annual winter meeting of Wyoming Section SRM, Cody. Delivered talk on history and research of HPGRS to Laramie County Historical Society. Delivered two lectures to RgMg-AnSc 3020, "Nutritional Management of Range & Pasture Herbivores," UW.
December: Delivered lecture to RgMg 4800, "Range Utilization & Grazing Management," UW. Attended XIII Range Beef Cow Symposium, Cheyenne; with Chris Mahelona, prepared exhibit on research of Rangeland Resources Research Unit and displayed it at Symposium.

SCHUMAN, GERALD E. -- G.E. Schuman has presented his research results related to soil quality and economic alternatives of marginal croplands to several Wyoming Conservation District groups at workshops. His research has shown that establishing grass on marginal, highly erodible croplands (CRP) has improved soil quality and has shown that forage production is an economically sound alternative to wheat-fallow rotation farming.

TOWNSEND, C.E. -- Application for variety plant protection and certification.

SEEDBED MODIFICATIONS FOR INCREASED SEEDLING SURVIVAL

D.T. Booth
Rangeland Resource Research Unit

CRIS: 5409-11210-001-00D

PROBLEM: Punch planting is a seeding technique where seeds are placed at the bottom of open holes punched deeper into the soil than the normal planting depth. The technique's advantages are: (1) moisture, temperature, and the concentration of soil salts in the immediate vicinity of the seed are usually more desirable than at the soil surface, (2) seedlings avoid soil crusts, and (3) are more protected from freezing, wind, and other environmental stresses. Punch planting has not been practical because punched holes sluff, and punch planting is too slow a method for planting large areas to grass. Punch planting is not too slow a method for species that are currently established by transplanting or for seeding small areas where a seed drill is not practical.

APPROACH: To over-come the problem of sluffing holes after punch planting, I conceived Cased Punch Planting (CPP) in which the hole is stabilized or cased with cellulosic plastic tubing which projects above the soil surface to prevent surface water from filling the hole with silt. I designed open-top, closed-top, and self-anchoring casings, using 1.3 and 2.4 cm diameter tubing of various lengths; and invented a hand tool to punch, case, and seed in one operation. CPP has been tested, with various tube configurations, through two field seasons, by comparing CPP plantings paired with standard seeding-depth spot plantings and include a test of CPP and standard seed spots sown through weed barrier fabric.

FINDINGS: The cellulosic tubes stabilized punched holes at a materials cost as low as 1.7 cents per hole. CPP was the superior method in all tests (Tables 1 - 3) except on level sandy clay loam soil where spring rains drowned cotyledon, and first-true-leaf stage CPP seedlings. Better seedling establishment accounted for most of the difference of CPP over the paired check plantings. Optimum tube configuration varied by species when casing diameter, length and top were variables (1992 weed barrier study, data not shown); but the 1.3 x 5.1 cm casing was best for all species in the 1993 study where casing top was not a variable (Table 4). Seedling mortality, while less for CPP than for the check, was higher than expected.

Table 1. Numbers of successful seedspots in Cased Punch Planting (CPP) weed barrier fabric study for 1992 (establishment) and 1993 (survival). There were 480 seedspot pairs.

SPECIES		(ALL CPP CASINGS)	PAIRED CHECKS	OSL[1]
Sagebrush	92	42	3	<.01
	93	18	2	<.01
Caragana	92	277	225	<.01
	93	215	161	<.01
Rabbitbrush	92	31	4	<.01
	93	19	3	<.01
Ponderosa	92	153	1	<.01
	93	41	0	<.01
Bitterbrush	92	140	128	.37 NS
	93	53	31	.01

[1]Observed significance level for 2-tailed probability, paired t-test.

Table 2. Seedling counts over all species for spring 1993 test of Cased Punch Planting.

Date and location	CPP (ALL CASINGS)	PAIRED CHECKS	OSL[3]
11 May			
Station[1]	445	102	
Eklund[2]	327	3	
Total:	772	105	<0.01
9 June			
Station	44	80	
Eklund	289	79	
Total:	333	159	<0.01
7 July			
Station	0	8	
Eklund	248	114	
Total:	248	122	<0.01
8 Sep			
Station	--	--	
Eklund	121	38	<0.01

[1]720 paired spots
[2]480 paired spots
[3]Observed significance level for 2-tailed probability, paired t-test.

Table 3. Numbers of successful seedspots for each species in spring 1993 Case Punch Planting study.

Date	Species	CPP	Check	OSL[1]
11 May				
	Sagebrush	244	1	<0.01
	Winterfat	347	89	<0.01
	White Prairie Clover	183	15	<0.01
8 Sep				
	Sagebrush	18	0	<0.01
	Winterfat	41	7	<0.01
	White Prairie Clover	62	31	<0.01

[1]Observed significance level for 2-tailed probability, paired t-test.

Table 4. Influence of Cased Punch Planting casing configuration on seedling numbers in spring 1993 study.

Date	Species	Significant casing variable + means[1]	OSL
11 May	ARTR[2]	diameter 1.3 = 132, 2.5 = 112	0.05
	EULA[3]	no difference among casings	
	PECA[4]	diameter x length 1.3 x 5.1 = 52 2.5 x 7.6 = 51 1.3 x 7.6 = 40 2.5 x 5.1 = 40 LSD = 12	0.02
8 Sep	ARTR	diameter x length 1.3 x 5.1 = 12 others $\leq$ 3 LSD = 6	<0.01
	EULA	diameter x length 1.3 x 5.1 = 22 others $\leq$ 9 LSD = 7	0.03
	PECA	diameter x length 1.3 x 5.1 = 20 2.5 x 5.1 = 17 1.3 x 7.6 = 8 2.5 x 7.6 = 17 LSD = 9	0.05

[1]Number of seedlings
[2,3,4]ARTR = Sagebrush; EULA = winterfat; PECA= white prairie clover

INTERPRETATION: The initial tests of CPP are positive, but do indicate that seedling survival should be improved to gain full benefit of the much higher seedling establishment obtained by CPP. Much of this improvement will likely occur when only optimum tube configurations are used. Closed-top casing are beneficial, but currently must be made by hand. Mechanization of closed-top casing construction may be possible, or other means may be developed to gain the same benefit. The use of hill-and-furrow seedbeds on level areas subject to ponding will help avoid drowned seedlings. Other possibilities for increasing seedling survival include planting earlier in the season and the use of soil amendments like vermiculite. CPP is an effective means of holding small or fluffy, surface sown species, like sagebrush and winterfat, in place without burying the seed. For that reason CPP has an added advantage for use on small areas where seed might otherwise be removed from the site by wind. CPP was demonstrated to be a convenient means of seeding through weed barrier fabric. However, if a seeding is to be made through fabric, the fabric should be installed 6 to 12 months ahead of planting so that desirable soil moisture conditions will exist when the seed is sown. The fabric should also be well stapled to the soil at planting spots. The overall success of CPP suggests its potential to improve our capability to direct seed our native trees, shrubs and flowers. CPP with the hand tool will likely be used for those species and situations, where hand planting or transplanting is now used.

FUTURE PLANS: We will continuing testing CPP to find methods for increasing seedling survival while retaining the advantage in seedling establishment. Fall seedings of winterfat, bitterbrush, and fourwing saltbush are currently being tested. In particular we are testing the use of vermiculite as seed covering in open-top tubes.

LEGUMES FOR RANGELANDS: DRYLAND ALFALFA

J.A. Morgan and G.E. Schuman
Rangeland Resources Research Unit

CRIS: 5409-11210-001-00D

PROBLEM: Productivity of the short-grass prairie of the USA is limited primarily by water and N. Since N fertilization of rangelands in this region is not economically feasible, the possibility of introducing N-fixing legumes into the prairie is being investigated as a means for improving the quality and quantity of forage. Incorporating legumes into semi-arid rangelands will be difficult given the characteristic low rainfall of this region. Research will focus on drought resistance, competition and growth of appropriate legumes under the characteristic semi-arid conditions of the Central Great Plains. Information gained from these studies will help evaluate how and under what conditions legumes may be successfully utilized for enhancing productivity while maintaining sustainability of rangelands.

APPROACH: Through strategic planning sessions of the Rangeland Resources Research Unit, a review of the literature, and consultations with several range scientists, we identified two critical research needs that address the problem of utilizing legumes in rangelands. The first addresses the successful incorporation and maintenance of legumes in western rangelands, and will require research into seedling establishment and persistence. A field study to be conducted at the High Plains Grasslands Research Station in Cheyenne has been planned to examine establishment and persistence of alfalfa grown in pure culture and in combination with grasses. Alfalfa and alfalfa/grass mixtures will be planted at different densities and maintained at two water regimes (irrigated and dryland). Plots will be subjected to different clipping (simulated grazing) regimes to study the influence of defoliation frequency on persistence. Long-term (more than 3 years) persistence of treatments will be examined in relation to treatment effects on soil and plant water relations, and the accumulation of carbohydrate and nitrogen compounds in crown tissue.

A second critical need is to obtain adapted alfalfa cultivars for use in grazing rangelands. A collaborative study with the USDA-ARS Forage and Range Research Unit in Logan, Utah has been planned to select for a grazing-type alfalfa. Field plots are being established at four locations: two in the inter-mountain area, and at Cheyenne, WY and the Central Plains Experimental Range near Nunn, CO. These locations vary in both rainfall amounts and patterns, and contain variable native plant communities and plant types (e.g., C_3 vs. C_4). Approximately 25 cultivars or accessions of alfalfa will be evaluated; traits examined will include growth, plant water relations, crown tissue carbohydrate and nitrogen compounds, development, and morphology. Kay Asay (USDA-ARS Forage and Range Research, Logan, UT) will be responsible for plant adaptability evaluations and breeding. Jack Morgan will work primarily on physiological aspects of plant response to the environment (water relations, carbohydrate and N metabolism).

FINDINGS AND INTERPRETATION: As the projects above represent new research initiatives, we have no research findings to report. We have identified suitable field plots at Cheyenne for the persistence and genetics studies, and a site at the CPER for the genetics work. Work is currently underway to characterize these sites and prepare them.

FUTURE PLANS: The persistence study at Cheyenne will be planted this spring, and evaluated for several years. Information from this study will be used to help build a simple, empirical model for predicting suitable environments for managing alfalfa on western rangelands. The results will be used to develop intelligent management strategies for maintaining legumes in rangelands.

The breeding/physiology study will be planted in the inter-mountain area and at Cheyenne and CPER this spring. Selections from these locations will be seeded into additional locations in the ensuing years where plant selection will occur under grazed conditions.

RESPONSES OF MYCOTROPHIC RANGELAND GRASSES TO CO_2 & WATER

J.A. Morgan, D.R. LeCain, and J.J. Read
Rangeland Resources Research Unit

CRIS: 5409-11210-001-00D

PROBLEM: Historical trends and current projections of future patterns in atmospheric CO_2 levels strongly indicate a continued enrichment in global CO_2. Projections of CO_2-induced climate changes are less certain, but include altered rainfall patterns and temperature regimes. As plant growth is responsive to CO_2, temperature and water, changes in atmospheric CO_2 and/or climate are bound to have significant impacts on plant productivity and species composition of some ecosystems. This is especially true for the short-grass prairie in the Central Great Plains of the United States, where plant species composition and seasonal growth dynamics are highly conditioned by limited soil water supply. An understanding of how prairie grasses may respond to long-term growth at elevated CO_2 will be required in order to intelligently manage rangelands in future CO_2-enriched atmospheres.

APPROACH: Photosynthesis, growth, plant N uptake, water and nitrogen use efficiencies, and carbohydrate metabolism were evaluated in growth chamber-grown western wheatgrass and blue grama, important C_3 and C_4 grasses of the Central Great Plains. Measurements were conducted on plants grown in a native soil under various CO_2, water and temperature regimes. The Grassland Ecosystem Model (GEM) was utilized to evaluate some of the gas exchange responses. Drs. Phil Harrison and N.J. Chatterton (both Logan, UT, USDA-ARS) collaborated on carbohydrate measurements. Dr. Bill Hunt (Colorado State Univ., Natural Resource Ecology Lab) directed modeling work.

FINDINGS: Results from a three-year experiment at Duke University conducted on unfertilized, intact prairie sods of western wheatgrass (C_3) and blue grama (C_4) revealed that growth and photosynthetic responses of both grass species to CO_2 enrichment and temperature were conditioned by N, with high CO_2-grown plants consistently exhibiting low tissue N concentrations. Gas exchange measurements also indicated lowered photosynthetic capacity in plants grown under enriched [CO_2]. A modeling exercise utilizing the Grassland Ecosystem Model revealed that photosynthetic acclimation of the plants to elevated CO_2 could be accounted for by considering the CO_2-related lowering of leaf N.

Growth-chamber studies conducted at the Crops Research Lab in Fort Collins, CO corroborated our earlier work at Duke in that plants exhibited some photosynthetic down-regulation when grown under enriched [CO_2], especially blue grama. The photosynthetic acclimation was related to reductions in plant tissue [N] and/or increased soluble carbohydrate accumulation. Blue grama plants had increased C partitioning belowground and twice the level of vesicular-arbuscular mycorrhizal (VAM) infection when grown at twice current atmospheric CO_2 concentrations compared to plants grown under current ambient CO_2 concentrations. These CO_2-

induced changes led to increased leaf water potentials and water use efficiency, but had little impact on nutrient acquisition or extraction of soil water at low soil water content. The results suggest that increased atmospheric CO_2 concentrations may indirectly benefit host plants via changes in VAM colonization.

Photosynthesis of blue grama has consistently responded positively to increases in CO_2 above current ambient concentrations, while growth of this C_4 species has either remained unresponsive to CO_2, or increased with a doubling over present ambient CO_2 concentrations. Moderate water stress and high temperatures appear to increase the sensitivity of growth to CO_2 in blue grama.

INTERPRETATION: Our growth-chamber studies have indicated significant increases in photosynthesis and generally enhanced growth of both species as a result of CO_2 enrichment, with the largest responses generally being observed for the C_3 species, western wheatgrass. Our results indicate that significant growth responses of blue grama, the C_4 species, should be expected in water-limiting, warm environments, and may be a significant factor in the response of future ecosystems to global change. Our studies also show that both species sometimes acclimate to long-term growth under different CO_2 and temperature regimes, and that these adjustments in plant metabolism will need to be understood in order to predict the outcome of possible climate change scenarios.

FUTURE PLANS: Two CO_2-enrichment studies are currently underway. In one study involving collaborators from CSU (Bill Hunt & doctoral student Carol Jacobs-Carre), Front Range Community College (Bill Knight), and Utah State Univ. (Lynn Dudley), we are studying how the physiology of the above two prairie grasses and associated mycorrhizae are affected by growth at different CO_2 regimes and varying levels of water availability. In another growth-chamber study, Dan LeCain and Jack Morgan are comparing the growth and photosynthetic responses of C_4 prairie grasses to determine the variation among C_4 plants in their ability to respond photosynthetically to CO_2. The addition of Carol Jacobs-Carre to our CO_2 project will allow us to continue using the Grassland Ecosystem Model to extrapolate our results. This work will be done in collaboration with Bill Hunt, who will serve as Carol's major professor, with myself as a co-advisor. Carol's PhD work will involve studying how defoliation influences plant response to CO_2, and also synthesizing and incorporating our experimental results into the Grassland Ecosystem Model. Consultations are underway with Bert Drake and others to consider open-top chamber studies on the shortgrass steppe in Colorado for studying the influence of CO_2 of prairie grass responses.

CICER MILKVETCH INVESTIGATIONS

C.E. Townsend
Rangeland Resources Research Unit

CRIS: 5409-11210-001-00D

PROBLEM: Considerable progress has been made in the 'domestication' of cicer milkvetch. There is, however, a continual need (a) to improve seedling emergence and stand establishment and (b) to improve forage yield. Seedling tolerance to a post-emergence herbicide such as 2,4-D amine would be of substantial value for improving stand establishment.

APPROACH: After significant genetic variability for a trait under investigation has been found, recurrent selection is used to select for the desired trait.

Photoperiod-Induced Dormancy

FINDINGS: After the photoperiod-induced-dormancy trait that is expressed about mid-summer (late July-early August) was removed by recurrent selection, extended plant height (length of longest stem) and herbage yield were significantly improved. Extended plant height relative to the cultivar Monarch was increased 105, 108, and 114% in the first, second, and third harvests, respectively, by two cycles of recurrent selection. Mean plant herbage yield was increased 113, 107, 116, and 111% of that of Monarch for the first, second, and third harvests and for total yield, respectively, by two cycles of recurrent selection. Plant spread was increased concomitantly with selection for increased herbage yield and extended plant height. Heritability estimates based on the regression of Cycle 2 progeny means on Cycle 2 parental values were low for extended plant height and herbage yield at all harvests. The 15 clones with the best performing polycross progenies for extended plant height and herbage yield were used as the parents of the cultivar Windsor. These data have been summarized and submitted to Crop Science for review.

An exclusive release of Windsor was made to the Peterson Seed Co., Inc., Savage, MN. Windsor was a cooperative effort involving ARS and the Colorado and Wyoming Agricultural Experiment Stations.

A varietal registration article was prepared for publication in Crop Science. Application has also been made for a Plant Variety Protection Certificate.

INTERPRETATION: These studies demonstrate that the herbage yield of cicer milkvetch can be increased to a level very similar to that of alfalfa.

FUTURE PLANS: Windsor is being evaluated at a number locations in the U.S., and also in Canada, western Europe, and New Zealand. Seed of Windsor will continue to be provided to

individuals who wish to evaluate it. A limited amount of seed will be available for commercial production this spring. Three germplasms that were developed in the process of developing and evaluating Windsor are in the process of being released.

Selection for Tolerance to 2,4-D:

FINDINGS: The data collected over five cycles of recurrent selection for tolerance to 2,4-D have been summarized. Briefly, five cycles of recurrent selection in the greenhouse for regrowth at the apical meristem following treatment with 2,4-D (1.0 kg a.i. ha^{-1} rate) increased extended seedling height (length of longest stem) and shoot dry weight by 38 and 21%, respectively, over that of the original population (Monarch). For Cycles 1 through 5 extended height was significantly correlated with shoot ($r=0.991$), root (0.934), and total seedling (0.970) dry weights, and apical meristem score (-0.969, 1=best, 5=no regrowth), but not with crown meristem score (0.547). When extended height, shoot, root, and total seedling dry weights, apical meristem score, and crown meristem score were regressed on cycle of selection (Cycles 1 through 5), the simple correlation coefficients were 0.995, 0.995, 0.937, 0.974, -0.974 and 0.545, respectively.

INTERPRETATION: Recurrent selection for increased regrowth at the apical meristem following application of 2,4-D was an effective and inexpensive procedure for increasing the tolerance of cicer milkvetch to 2,4-D.

FUTURE PLANS: A manuscript has been prepared and will be submitted to Crop Science. A germplasm release notice for this material is being prepared.

Cytogenetics of Cicer Milkvetch (cooperative with Dr. R.L. Latterell)

FINDINGS: The meiotic analysis of polyhaploid plants has been completed. The polyhaploids were obtained from twin seedlings.
Meiotic behavior of polyhaploids ($2n=4x=32$) was strongly diploid-like. Bivalent frequencies exceeded 95% in the four plants studied, and a majority of meiotic configurations comprised exclusively bivalents. Meiosis was highly regular in two polyhaploids plants, whereas the other two polyhaploids produced a greater diversity of configurations reflecting their markedly higher frequencies of univalents. Optimization analysis revealed close correspondence to the 2:2 pattern of chromosome pairing expected of amphidiploids and estimates of x (relative genomic affinity) approximated 1.0 indicating that chromosome pairing was almost exclusively intragenomic.

INTERPRETATION: Polyhaploids of cicer milkvetch evidently comprise two pairs of distinct genomes (AABB) which pair preferentially (homologously). Natural octaploids of cicer milkvetch are therefore autoallooctaploids with genomic formula AAAABBBB. Diploid-like meiotic behavior of octaploid plants, despite the autotetraploid nature of constituent genomes, suggest that multivalent formation was suppressed and bivalent frequencies thereby enhanced by a bivalentization gene system.

FUTURE PLANS: These data have been summarized and submitted to the International Journal of Plant Sciences for publication.

Tolerance of cicer milkvetch to low Ph soils (cooperative with R.A. Bowman)

FINDINGS: The third phase of this study has been completed, but the data have not been completely analyzed.

FUTURE PLANS: After completing data analyses, the information will be summarized and prepared for publication.

PHYSIOLOGY AND GENETICS OF ISOFLAVONOID ACCUMULATION IN CICER MILKVETCH

A.W. Lenssen, C.E. Townsend, and S.S. Martin*
Rangeland Resources Research Unit
Sugarbeet Production Research Unit*

CRIS: 5409-11210-001-00D

PROBLEM: Cicer milkvetch is a perennial, N_2-fixing, nonbloating forage legume adapted to temperate environments. However, ruminants grazing pure stands of cicer milkvetch have become photosensitized in some environments. Isoflavonoids are involved with diverse biological activities, including estrogenism, disease resistance, and potentially, photosensitization.

APPROACH: We initiated a series of studies investigating cicer milkvetch to identify factors that influence the accumulation of isoflavonoids. In separate greenhouse studies, elicited leaflets from the parental genotypes (clones) of the cultivars Monarch and Windsor were analyzed for isoflavonoid accumulation. Growth chamber studies were conducted to investigate the influence of genotype on leaflet isoflavonoid concentrations following different UV-C exposure times, incubation times, shoot positions, and growth x incubation temperatures.

FINDINGS: In both parental pools, genotypes differed significantly for the accumulation of mucronulatol, astraciceran, astracicerone, and cajanin. The interactions of genotype x UV-C exposure time, genotype x incubation time, genotype x shoot position, and genotype x incubation temperature were significant for mucronulatol, astraciceran, maackiain, astracicerone, cajanin, and biochanin A. Genotype strongly influenced qualitative and quantitative accumulation of isoflavonoids in cicer milkvetch.

INTERPRETATION: Accumulation of isoflavonoids in cicer milkvetch is influenced by plant genotype and environment. The prospects are promising for reducing the accumulation of isoflavonoids by breeding and genetics. Thus, the development of varieties with little or no isoflavonoids appears to be possible.

FUTURE PLANS: The genotype x environment phase of the research has been summarized and submitted to a refereed journal for review.

The second year of the postdoctoral research associate position was completed. Funding is not available to continue this research. Therefore, the remaining data will be summarized, and, if appropriate, they will be submitted to a refereed journal for review.

ALFALFA INVESTIGATIONS

C.E. Townsend
Rangeland Resources Research Unit

CRIS: 5409-11210-001-00D

PROBLEM: The yellow-flowered alfalfas (Medicago sativa ssp. falcata) are better adapted than the purple-flowered alfalfas (Medicago sativa ssp. sativa) to the harsh range sites of the central and northern Great Plains. In general, improved germplasm of yellow-flowered alfalfa for use in a breeding program is not available. Therefore, germplasms for the development of varieties of yellow-flowered alfalfa or for crossing with purple-flowered alfalfa need to be synthesized.

APPROACH: In 1978, 73 entries of the yellow-flowered, purple-flowered complex were established in single row, replicated plots at the Central Plains Experimental Range (CPER). Seedling emergence and stand established were excellent for all entries. These same 73 accessions plus 24 more were also established in a spaced-plant replicated nursery at the C.S.U. Agronomy Farm near Fort Collins in 1978. All non-yellow-flowered plants were rogued in the latter nursery.

FINDINGS: In April 1993, plants were dug from nine of the best persisting entries seeded in 1978 at the CPER. Percent stand for these nine entries ranged from 63 to 88 with a mean of 75. About 12 plants were selected from each entry and transplanted to a site at the former C.S.U. Agronomy Farm. Although all plants had medium to large taproots, some had more fibrous roots than others. These plants were covered with a pollination cage and honey bees served as pollinators. Flower color ranged from purple to yellow. Most plants produced some seed. Seed was harvested and composited according to flower color and pod shape (falcate to one or more coils).

Germplasm release notices have been prepared for four germplasms developed from the planting made at the CPER and for three germplasms developed from the spaced-plant nursery established on the C.S.U. Agronomy Farm. These germplasms include (a) two falcata-types and two sativa-types that persisted for 10 or more years at the CPER and (b) diploid and tetraploid forms of yellow-flowered alfalfa as well as a yellow-flowered type (ploidy level unknown) that tends to spread.

INTERPRETATION: The germplasms developed from the CPER plantings should be an excellent source of genetic material for the development of cultivars adapted to the 30 cm precipitation zone of the central Great Plains. The diploid, tetraploid, and spreading germplasms will be useful for breeding and genetic studies.

FUTURE PLANS: Distribute seed of these germplasms to interested parties. Prepare registration articles of these germplasms for publication in Crop Science.

LONG-TERM DECOMPOSITION OF WOOD RESIDUE AMENDMENTS

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CRIS: 5409-12130-001-00D

PROBLEM: Wood residues are being used as a amendment to reclaim abandoned bentonite mined lands. The amendment is being used to improve the physical characteristics of the clay spoil to improve water infiltration and leaching of soluble salts. If decomposition of the wood residue occurs too quickly the high clay, sodic spoils will become sealed and limited water infiltration will result and revegetation will be impossible. The wood residue amendments must persist long enough for newly established vegetation to aid in the development of soil structure so that the material does not return to its original impermeable and crusted state.

APPROACH: Wood residues were applied to bentonite spoils at the rate of 0, 45, 90, and 135 Mg/ha in 1981 at a field study in northeastern Wyoming. Nitrogen fertilizer was applied at the rates of 0, 2.5, 5.0, and 7.5 kg N/ Mg of wood residue. These plots were revegetated in 1981 and litter bags placed at about 7.5 cm depth within the wood residue by nitrogen treatment plots in 1983. In 1993, 192 litter bags were excavated from the plots and the percent decomposition determined using an ashing technique. This data represented the decomposition during a 10 year period.

FINDINGS: Earlier studies evaluated the decomposition of the wood residues at 1, 2, 3, and 5 years. Decomposition, after 5 years, averaged 26.3%. During the initial 5 years decomposition responded to nitrogen application averaging 10.6, 14.3, 18.8, and 20.8% for the 0, 2.5, 5.0, and 7.5 kg N/ Mg wood residue treatments, respectively. After 10 years, decomposition averaged 31% and it was not affected by wood residue or nitrogen fertilizer application rate. It appears that between year 5 and 10 decomposition achieved an equilibrium and the single initial nitrogen fertilizer application no longer had any effect on the decomposition rate.

INTERPRETATION: Wood residue decomposition is occurring at a slow enough rate that plant establishment can be sustained and aid in the development of soil structure in the "new soil". The wood residue should continue to ensure improved water infiltration and salt leaching, which will result in improved chemical and physical quality of the spoil. The fact that decomposition is similar for all nitrogen treatments indicates that the single nitrogen application that occurred in 1981 did not continue to influence decomposition as it did during the first 5 years.

FUTURE PLANS: This study is complete. Data analysis will be completed in 1994 and a manuscript prepared on the long-term decomposition of the wood residues. Much interest was generated by the paper that was published on the first 5 years of data. Use of tree trimmings and lawn wastes on land is becoming more important since landfill space is becoming so limited.

UTILIZATION OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTES ON SEMIARID RANGELANDS HYDROLOGY, SOILS, AND VEGETATION

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CRIS: 5409-12130-001-00D

PROBLEM: The plant, soil, and water components of semiarid rangeland ecosystems are in a general equilibrium state. To improve the productivity of the land and to reduce potential offsite water problems it is necessary to provide increased nutrient availability and reduce the quantity of water which leaves the land in overland flow. At the same time there is an increasing need for land suitable for safe utilization of an increasing quantity of animal, municipal, and industrial waste products. There exists the possibility that the surface application of the waste products to rangelands can increase the quantity and quality of the forage grown on the land and improve soil properties allowing a greater portion of the precipitation to infiltrate and be utilized by the growing plants. At the same time care must be taken to insure the applied waste products do not degrade the quality of any water which might leave the site either as surface or subsurface flow.

APPROACH: Two study sites were established in 1993. One at the Central Plains Experimental Range (CPER) near Nunn, Colorado, and the other at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, Wyoming. At each site a series of thirty 9X9-m plots for vegetation/soil quality evaluations and twenty 3X9-m plots for hydrologic investigations were established. Treatments consisted of surface applications of (1) fresh animal waste, (2) composted animal waste, (3) composted sewage sludge, (4) phosphogypsum along with (6) control (no treatment). The treatments were applied in May 1993 at the rate of about 23 metric tons/ha. Soil samples were collected from all plots for baseline soil quality prior to waste application. Runoff water quality and quantity was evaluated on one-half of the hydrologic plots with a rotating boom rainfall simulator in May and all the hydrologic plots in August 1993. The May simulation was to assess the greatest potential hazard of water quality degradation since the simulations were carried out within a few days of waste application. Vegetation samples for evaluating species composition and forage production/quality were collected at peak production on the vegetation/soil quality plots.

FINDINGS: Analysis of the runoff water, plant, and soil samples are currently being accomplished. Runoff hydrographs are undergoing processing for evaluation of runoff quantity.

Plant production was increased by the application of composted sewage sludge and composted animal wastes. The fresh feedlot manure and the phosphogypsum did not affect plant production.

Treatment	CPER (kg/ha)	HPGRS (kg/ha)
Composted sewage sludge	1373	1457
Composted animal waste	1307	1542
Fresh animal waste	825	1198
Phosphogypsum	773	1193
Control (no treatment)	908	1189

INTERPRETATION: The composted waste materials have resulted in about a 30-35% increase in forage production. The phosphogypsum did not increase the production even though it contains about 6% calcium phosphate. These range soils are low in phosphorus; however, they are also generally low in nitrogen and the plants may not respond to the added phosphorus unless we apply a small amount of nitrogen to that treatment. Final hydrologic and water quality interpretation will have to wait for completion of the chemical analyses and runoff hydrograph processing.

FUTURE PLANS: The studies will be continued for a minimum of four more years. Soil samples will be collected in the spring of 1994 to assess the effect of waste application on soil quality. Plant production and species composition will also be evaluated in 1994 to assess any response to the waste treatments. We will fully assess the potential for water quality degradation from the wastes through thorough evaluation of the rainfall simulator runoff samples and the potential for leaching of nutrients and elements present in the wastes.

HIGHLY ERODIBLE CROPLANDS: SOIL QUALITY AND ECONOMICS

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CRIS: 5409-12130-001-00D

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the soil quality of marginal, highly erodible cropland. Alternative management of these lands to enable their regeneration and provide economic benefit must be evaluated.

APPROACH: Field sites were established in 1987 at Egbert, Keeline, and Arvada, Wyoming. Treatments include: (1) continuous wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat-fallow, (3) grass established on long-term wheat-fallow marginal cropland, and (4) native grassland. Soil samples are collected annually from all treatments to assess soil quality changes. Grass production data is also collected from the native rangeland and reseeded grass treatments. Wheat and straw production are also determined in the wheat-fallow cycle.

FINDINGS: Soil quality of the marginal cropland soils seeded to grass continue to exhibit improvements. Summarization of the 5 years of soil data is presently being accomplished to enable preparation of a publication on soil quality dynamics. The reseeded grass plots continue to show good forage production.

Site/Treatment	Forage Production (kg/ha)
Arvada	
Fertilized	3002
Unfertilized	2483
Keeline	
Fertilized	2589
Unfertilized	1747
Egbert	
Fertilized	2138
Unfertilized	1216

Litter and standing dead plant material has continued to increase on the reseeded grass plots.

These components now account for slightly over 50% of the aboveground biomass. This was identified by the SCS and ASCS personnel in Wyoming and Colorado as a concern as it relates to use of these lands for grazing or hay production after contract expiration. They would like research or demonstration plots established that would show the effects of cultural practices such as burning or mowing to reduce the litter and standing dead plant material. This large litter and standing dead component will reduce utilization and quality of the forage during the first couple of years. The production on the reseeded grass plots continues to be valued at the same or more than historic wheat production on these lands.

INTERPRETATIONS: The observed improvements in soil quality suggest that these lands can be restored to more productive sustainable lands. The forage production and economic evaluation points out that alternative uses of these lands that protects the soil resource is feasible and desirable.

FUTURE PLANS: We will continue to evaluate the soil quality changes resulting from the reestablishment of a grass community on these marginal croplands. We will also assess the possibility of responding to the request of SCS and ASCS as it relates to the management of these grasslands the last year or two of the contract period. Research has shown that as litter and standing dead material accumulates the plant community becomes decadent and less productive.

STRATEGIES FOR ESTABLISHMENT OF BIG SAGEBRUSH ON WYOMING MINED LANDS

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CRIS: 5409-12130-001-02R

PROBLEM: Wyoming big sagebrush is one of the most widely distributed and adapted shrub species in Wyoming and the region. Although considerable debate surrounds its value and use during mined land reclamation, the fact remains that it is sometimes required in attempts to restore these lands to predisturbance condition for wildlife habitat. Even though it is widely adapted to the region, establishment of big sagebrush from seed has been difficult to impossible. Therefore, this research was initiated to evaluate strategies and develop technologies for establishment of the species on mined lands.

APPROACH: A field study was established to evaluate and define effective seeding strategies for establishment of big sagebrush on degraded and disturbed rangelands. Specific objectives included the evaluation of: (1) Efficacy of direct-applied topsoil for enhanced sagebrush establishment through effects on sagebrush seed and VAM introduction, (2) The value of stubble mulch crop of annual grain for sagebrush establishment through effects on snow catch and microsite modification, (3) The usefulness of a surfically applied hay/straw mulch in improving sagebrush establishment through seed/seedling protection and microsite modification, (4) The effect of competition from concurrently seeded herbaceous species on the establishment of big sagebrush, and (5) The value of initially established fourwing saltbush as a pioneer species for later recruitment of sagebrush. The later objective will require several years for its evaluation.

FINDINGS: Fresh stripped topsoil has had a significant effect on the number of sagebrush seedlings that have become established. In the first year after seeding the sagebrush the seedling numbers were about 50 times higher on the fresh stripped topsoil compared to the 5-year old stockpiled topsoil. The fresh topsoil did not act as a seedbank but the improved soil characteristics improved seedling establishment. Sagebrush seedlings are still 2 times greater on the fresh stripped topsoil compared to the stockpiled topsoil 2 years later. The fact that we had a several fold increase in sagebrush seedlings from a single seeding made in February 1992 was unexpected since sagebrush seed research has shown that seed viability is short. VAM infection percentage of the sagebrush was not different for those sagebrush growing on the fresh compared to the stockpiled topsoil. Sagebrush seedling establishment was significantly improved by mulch treatment. This increase is attributed to greater soil moisture and microsite modification on the mulch treated plots compared to the control. The stubble treatment resulted in the greatest number of sagebrush seedlings becoming established. Competition of herbaceous species had a major impact on sagebrush seedling establishment. At the end of 2 years there

were 3 to 4 times more sagebrush seedlings established on those treatments where no herbaceous competition existed. Initial sagebrush seedling establishment in the first year was also significantly reduced by competition. Too short of time has elapsed to evaluate the role fourwing saltbush may play in the recruitment and establishment of big sagebrush. Fourwing saltbush has been established and is being overseeded with sagebrush.

INTERPRETATIONS: The research has shown that topsoil source, mulch and competition all significantly influence big sagebrush seedling establishment. Sagebrush plantings should be made in a small grain stubble with least herbaceous vegetation competition as is feasible to protect the soil and establish an acceptable vegetative community. The amount of competition that is acceptable needs to be further evaluated. Fresh stripped topsoil should be used; however, further research is needed to delineate those factors in the topsoil that is responsible for the greater sagebrush establishment.

FUTURE PLANS: This research will be continued and further investigation into the role VAM may be playing in the establishment and/or survival of big sagebrush seedling will be assessed. We will also continue to assess the role of the "pioneer" plant, fourwing saltbush, on sagebrush establishment.

Sagebrush seedling numbers (seedlings/m2) as affected by topsoil source, mulch type, grass competition, and time.

Treatment Variable	Spring 92	Fall 92	Spring 93	Fall 93
Topsoil Source				
Fresh	1.52	1.24	2.52	4.50
Stockpiled	0.03	0.03	0.48	2.26
Mulch Type				
Stubble	1.17	0.96	1.99	4.33
Surface	1.25	1.04	1.89	4.18
Stubble + Surface	0.66	0.54	1.68	3.12
Control	0.01	0	0.43	1.99
Grass Competition (kg PLS/ha)				
O	1.88	1.60	3.05	6.66
16	0.34	0.21	0.74	1.98
32	0.09	0.37	0.71	1.56

LONG-TERM GRAZING IMPACTS ON THE VEGETATIVE AND HYDROLOGIC CHARACTERISTICS OF A NATIVE SHORTGRASS PRAIRIE

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CRIS: 5409-31630-002-00D

PROBLEM: There currently exists a conception that long term heavy grazing by cattle has severely damaged both the vegetation (diversity, production, and density) and the water infiltration characteristics of the semiarid rangelands. A common belief is that with removal of the cattle, the areas will revert back to pristine conditions.

APPROACH: The Central Plains Experimental Range (CPER) near Nunn, Colorado, has a series of pastures that have experienced the same grazing intensity for the past 50 years, seasonlong-light, -moderate, and -heavy, and yearlong-moderate. A similar set of pastures with 12 years of grazing history exist at the High Plains Grasslands Research Station (HPGRS) near Cheyenne, Wyoming. At CPER 3-ha exclosures were constructed in each pasture to exclude large grazing animals. Within each exclosure a set of four 3- X 10-m plots are installed each year to measure the runoff/infiltration rates with a rotating boom rainfall simulator. Other initial measurements included soil porosity, soil bulk density, soil particle size distribution, and soil organic matter, all at 4 separate depths. Bulk density and particle size distribution were measured both in the interspaces and under the grass clumps. Vegetation density, composition and production are measured yearly in each exclosure. Slope and surface roughness measurements are made on each simulator plot. At HPGRS a similar set of simulator plots were installed within the pastures, but animals were not excluded. These measurements, replicated over time, will be used to evaluate the rate and extent of changes that might occur with the removal of the large grazing animals.

FINDINGS: Two years of data have been collected from the exclosures at CPER and one year from the plots at HPGRS. Preliminary data analysis shows an increase in runoff with increased past animal grazing intensity. To date no changes in runoff/infiltration are evident as a result of excluding animals (CPER). There are indications that the initial runoff from the plots in a dry state (dry run) is higher than from the same area which was wetted for 45 minutes and allowed to dry for 30 minutes (wet run)(Figure 1).

INTERPRETATION: Complete evaluation of the hypothesis will have to wait for time (additional years) to evaluate the rate that changes might occur in the infiltration/runoff rates as a result of livestock exclusion. We will also attempt to determine which vegetation and soil parameters are most affected by the removal of the cattle from the system.

FUTURE PLANS: The studies will be continued for a minimum of three more years. Included will be supplemental studies to characterize spatial variability in infiltration rates within a simulator plot allowing a more accurate modeling of the runoff process which will include the effect of the heterogeneous vegetative and surface roughness factors.

CARBON AND NITROGEN DYNAMICS IN GRAZING LANDS

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CRIS: 5409-31630-002-00D

PROBLEM: Longterm, heavy stocking rates has resulted in a decrease in the surface litter accumulation on the soil surface in a shortgrass prairie system. The objective was to evaluate whether grazing systems grazed at a heavy stocking rate effected the soil quality and hence sustainability of the grazing system.

APPROACH: Pastures grazed for the past 11 years at a heavy stocking rate were compared to continuous light grazing treatment and to a livestock exclosure. The heavy stocking rate (66.7 steer-days/ha) was evaluated under a continuous, rotationally deferred and a short-duration rotation grazing system. To evaluate the carbon and nitrogen dynamics of the various grazing treatments soil samples were collected in the summer of 1993 at the 0-3.8, 3.8-7.6, 7.6-15, and 15-30 cm depth increments. These soil samples were evaluated for total Kjeldahl nitrogen, total organic carbon, nitrogen mineralization potential, and respired carbon. Large diameter soil cores were also taken to assess root biomass and root nitrogen and carbon content. Aboveground biomass data were also collected. These data will enable a complete nitrogen and carbon balance of the system.

FINDINGS: Preliminary data evaluation shows that the soil quality is generally better in the grazed treatments compared to the nongrazed exclosures. Soil organic carbon was 13-30% lower, total Kjeldahl nitrogen was 7-21% lower, and respired CO_2 was 13-30% lower in the exclosures compared to the grazing treatments. Nitrogen mineralization potential was more variable and showed a 15% greater to 13% lower mineralization potential in the exclosures compared to the grazing treatments. The rotationally deferred treatment exhibited a decrease compared to the exclosure. This was the only example of a soil quality parameter being lower in a grazed pasture treatment. These differences reported represent the quantity of a specific parameter in the 30 cm soil depth; however, this trend is generally true for the individual soil depths evaluated.

INTERPRETATION: In general,these findings indicate that grazing rangelands results in a better quality soil than when grazing is excluded. The grazing has resulted in greater forage production, hence greater carbon dioxide sequestration from the atmosphere and greater soil organic carbon. In the nongrazed treatment we believe the soil nutrients are immobilized in the aboveground litter and standing dead plant material and are not readily available for cycling into the ecosystem. The analysis of the aboveground and root material will enable us to calculate a carbon and nitrogen balance for these systems.

FUTURE PLANS: We will sample, both soil and roots, to a greater depth in 1994 to enable us to account for a greater portion of the total carbon and nitrogen in the grassland system. We are also continuing the analysis of the plant material (live and dead) and root material to determine the contribution of those variables to the nitrogen and carbon balance.

GRASS: GRAZING RATES AND SYSTEMS STUDY

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PROBLEM: Claims for the benefits of short-duration rotation grazing systems have received a great deal of publicity and some official recognition by SCS and other agencies. A study was begun in 1982 to evaluate the response of cattle, vegetation and soils to three grazing systems at three stocking rates.

APPROACH: Crossbred and Hereford steers initially weighing 260 kg grazed native range 2 June-30 September 1993. Systems included continuous or season-long grazing (CG); rotationally deferred grazing in which grazing was deferred on one- fourth of each pasture until 1 September (RDG); and 8-paddock short-duration rotation grazing (SDRG). Grazing periods on the latter were adjusted according to assumed forage growth rate and forage supply, and ranged from 2 to 12 days in 1993. Light-, moderate- and heavy- stocked pastures were 40.9, 12 and 9 ha, respectively. Stocking rates in 1993 were 20.7 (light), 50.0 (moderate) and 66.7 (heavy) steer-days/ha. Steers were weighed every 28 days.

Peak standing crop (PSC) was estimated inside 4 exclosures per pasture 22-29 July. In July, PSC was estimated by clipping two 0.2-m^2 quadrats inside each exclosure on the light- and heavy-stocked pastures. Clipped herbage was divided into warm-season grasses, western wheatgrass, needle-and-thread, other cool-season grasses, sedges, and forbs. On the moderate-stocked pastures, PSC was estimated with an electronic herbage meter. The two quadrats in 12 of the exclosures on the heavy-stocked pastures were metered as well as clipped and weighed; the regression of weight on meter readings from these quadrats was used to estimate weights on the quadrats in the moderate-stocked pastures. Correlation of weights and meter readings (r^2) in July were only 0.06, but because the range of standing crop was small, the 95% confidence interval was 72 kg/ha at mean meter reading and 201 kg/ha at the most extreme reading.

Biomass remaining after grazing was estimated on 1 (continuous light), 13 (remaining pastures except rep 2 continuous), and 22 October (rep 2 continuous), on five quadrats outside each exclosure. Correlation (r^2) between meter readings and clipped biomass was 0.70 on 1, 0.75 on 13, and 0.93 on 22 October.

Cover of all plant species, litter and bare ground was estimated with an inclined point quadrat 28-30 June. Ten points were recorded at 50 locations along each of two transects (one on valley bottom, one on slope) in each light- and heavy-stocked pasture.

FINDINGS: PSC averaged 930 kg/ha over all pastures; stocking rates and systems had little effect on production. Forage utilization was 9, 35 and 44% under light, moderate and heavy stocking, respectively.

Effects of stocking rates and grazing systems on cover were:

Cover category	System and stocking rate			
	CG Light	CG Heavy	RDG Heavy	S D R G Heavy
	Cover, %			
Blue grama	3.0 b	4.8 a	5.4 a	4.6 a
Cool-season graminoids	3.7 a	2.1 a	2.2 a	2.8 a
Forbs	0.7 a	1.3 a	1.6 a	0.8 a
Total plant cover*	7.4 a	8.0 a	9.1 a	8.2 a
Litter cover	85.0 a	64.0 b	68.6 b	69.4 b
Bare ground	4.4 b	22.2 a	16.0 a	14.8 a

* Excludes mosses and lichens.

Effects of stocking rates and grazing systems on peak standing crop were:

Plant category	System and stocking rate						
	CL	CM	CH	RM	RH	SM	SH
	PSC, kg/ha						
Warm-season grasses	180	-	186	-	257	-	221
Western wheatgrass	478	-	158	-	32	-	162
Needle-and-thread	135	-	88	-	170	-	103
Other cool-season	46	-	95	-	88	-	58
Sedges	103	-	54	-	88	-	62
Forbs	247	-	229	-	280	-	414
Total	1189	843	809	851	958	815	1020

Average daily gains were:

Grazing system	Stocking rate		
	Light	Moderate	Heavy
	ADG, kg		
Continuous	1.12a	0.95b	0.80c
Rotationally deferred	--	0.98b	0.84c
Short-duration rotation	--	1.01b	0.79c

INTERPRETATION: Cattle gains decreased with increasing stocking rate under all three systems; all differences among stocking rates were significant, but differences among systems were not. Neither grazing system nor stocking rate had any significant effect on biomass at peak standing crop, although total biomass and biomass of cool-season grasses tended to be higher under light stocking, and biomass of forbs tended to be higher under heavy stocking on short-duration rotation grazing. Litter cover decreased and percent bare ground and cover of blue grama increased under heavy stocking. A trend toward more bare ground under continuous grazing than under the two other systems may be developing. Otherwise, no effects of specialized grazing systems have been detected after 11 years.

FUTURE PLANS: This study will be continued through 1994; stocking rates will remain at 1993 levels. Originally it was planned to end the study in 1993, after three full cycles of rotational deferment. However, we were unable to recruit a graduate student in 1992 to carry out two years of detailed vegetation measurements; one was recruited in 1993. A second graduate student, funded with a grant, was recruited to study C and N cycling. His results, and results of hydrologic studies on the pastures, are reported elsewhere.

LONG-TERM GRAZING INTENSITY STUDY CENTRAL PLAINS EXPERIMENTAL RANGE

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CRIS: 5409-31630-002-00D

PROBLEM: Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

APPROACH: In 1940, a replicated study of 3 grazing intensities was set up at the Central Plains Experimental Range. Over the years replications were dropped until a single pasture of each of 3 treatments remains. The treatments are light, moderate and heavy stocking on summer-long (May to October) grazing. The year-long moderate pasture was excluded from this long-term study in 1993 because it had only been grazed year-long since 1973 and is an atypical pasture for the area. Heifer gains were recorded in most years, and plant productivity and botanical composition were estimated by various means in many years. Initial measurements of botanical composition were by the "square foot density" method, which is not directly comparable to basal or foliar cover.

In 1993, the light, moderate and heavy pastures were stocked at 15, 20 and 30 yearling heifers per 129.6 ha (320 acres), respectively. Heifers weighed 274 kg when grazing began 14 May 1993. Grazing ended on 16 October 1993 and heifers were weighed every 4 weeks.

Basal and foliar cover of all plant species was estimated with a 10-pin inclined point quadrat. Quadrats were placed at 5, 6, 7, 8 and 9 meters from each of 20 permanent stakes placed in the large exclosure in each pasture, and the same distances from 20 cages outside the exclosure. Cover estimates are derived from a total of 1000 points inside and outside in each pasture. Plant production was estimated for plots distributed over the entire area of each pasture and also for the permanent plots located in and out of the exclosures in each pasture. Frequency of occurrence of plant species was also sampled on the exclosure plots.

FINDINGS: Stocking rates and cattle gains were:

Treatment	Head/ 320 A	Head/ ha	Weight, kg 14 May	7 Oct	ADG
Light	15	0.116	273	368	0.65
Moderate	20	0.154	274	362	0.60
Heavy	30	0.232	274	356	0.56

Forage production from the pasture plots was 550, 515 and 425 kg/ha on light, moderate and heavy-stocked pastures, respectively; after grazing, 288, 307 and 206 kg/ha remained, for utilization of 48, 40 and 52%, respectively. Inside the exclosures, production was 534, 761 and 574 kg/ha; immediately outside the exclosures production was 618, 455 and 425 kg/ha of forage under light, moderate and heavy stocking, respectively.

Basal and foliar cover estimates including major species were:

Cover class		% Basal cover Light	Mod.	Heavy	% Foliar cover Light	Mod.	Heavy
Bare ground	In	19.2	13.3	15.5	7.1	6.1	6.5
	Out	22.1	20.0	21.1	11.5	10.1	10.3
Litter	In	61.1	63.6	61.2	44.3	29.0	34.6
	Out	54.4	54.4	45.4	34.1	27.8	22.2
Blue grama	In	6.6	13.4	9.9	12.7	26.4	24.8
	Out	7.4	19.2	18.2	20.9	45.2	43.8
Western wheatgrass	In	0.0	1.0	0.2	0.2	9.6	0.3
	Out	0.0	0.2	0.0	0.2	0.2	0.0
Needle-and-thread	In	2.4	0.1	0.8	9.7	0.4	3.5
	Out	0.6	0.2	0.0	3.2	0.3	0.0
Sand dropseed	In	0.0	0.0	0.1	0.0	0.0	0.1
	Out	0.2	0.0	0.1	0.4	0.0	0.2
Sedges	In	0.7	0.3	0.8	5.1	1.9	6.1
	Out	0.2	1.0	1.1	2.0	4.5	7.6
Plains pricklypear	In	4.1	2.0	3.1	6.2	3.2	5.4
	Out	3.1	0.3	1.8	5.4	0.8	3.2
Fringed sagewort	In	2.9	2.3	1.6	8.2	7.3	8.0
	Out	1.1	0.1	0.0	7.7	0.3	0.0
Total plant	In	18.1	23.1	18.0	47.3	64.9	56.8
	Out	14.8	24.6	23.6	53.0	61.4	62.8

A Rangeland Resources Research Unit publication titled: Plant Community and Cattle Responses to Fifty Years of Grazing on Shortgrass Prairie was published in June of 1993, describing some of the plant responses and cattle gains during the first 54 years of this study.

INTERPRETATION: Heifer gains declined with increasing stocking rate, with no indication that any rate was below the critical stocking rate. Forage production was below normal in general and also declined with increased stocking. Desired levels of utilization were achieved in the heavy and moderate pastures but the light pasture was actually grazed more heavily than

the moderate pasture, partly because of the low annual production. Foliar cover estimates were naturally higher than basal cover estimates, but followed the same pattern. Litter cover was less and blue grama cover was more outside than inside exclosures. Outside the exclosures, litter cover decreased and blue grama cover increased as stocking rate increased. Western wheatgrass cover was much higher in the exclosure of the moderately-stocked pasture than at any other location, indicating that this exclosure is uncharacteristic of the study area.

FUTURE PLANS: This study will be continued indefinitely. Cover will be estimated inside and outside the exclosures and on the plots distributed over the entire area of each pasture during the next two years, and a manuscript will be prepared for publication. A graduate student has been recruited to analyze and interpret data from other long-term studies at CPER and prepare manuscripts for publication.

MONITORING RANCH-SCALE TIME-CONTROLLED GRAZING SYSTEMS

R.H. Hart
Rangeland Resources Research Unit

CRIS: 5409-31630-002-00D

PROBLEM: Some producers and action-agency personnel have expressed doubts about the applicability of our grazing systems research, because paddock sizes and numbers are smaller than in most ranch-scale systems.

APPROACH: In 1990, the HR Land Co. established a 47-paddock time-controlled rotation grazing system on about 2225 ha (5500 A) of rangeland (R) and crested wheatgrass (CW) pasture east of Cheyenne. They invited ARS to monitor vegetation on the system. We established six 50-m cover transects in three paddocks of the system and placed an exclosure near each transect. Similar transects and exclosures were placed on adjacent land, grazed seasonlong, of the Wyoming Hereford Ranch (WHR) and Hirsig's ranch. Peak standing crop, cover and utilization were estimated as in GRASS above; cover on 8 and 9 July, standing crop on 16 August, and utilization on 27 October 1993. Correlation of meter readings with standing crop (r^2) was 0.80 and 0.95 in July and October respectively.

FINDINGS: Production and utilization were:

Vegetation type	Ranch	Production	Use
		kg/ha	%
Crested wheatgrass	HR Land	1380	69
	WHR	2220	68
Range	HR Land	2240	69
	WHR	1630	40
	Hirsig	1270	43

Cover estimates were:

Type	Ranch	Warm-seas. grass	Cool-seas. nat. Per.	Cool-seas. grass Ann.	Agde	Sedge	Forbs	Bare	Litter
		%							
CW	HR Land	2.9a	0.1a	0.0a	0.5b	0.1a	2.2b	46.2a	47.8a
	WHR	4.2a	0.2a	0.0a	2.2a	0.0a	5.6a	30.6a	55.4a
Range	HR Land	6.9a	2.7a	0.3a	0.0a	0.9a	0.9a	19.7a	67.0a
	WHR	5.7a	7.3a	0.2a	0.1a	2.5a	2.4a	11.0b	70.7a
	Hirsig	11.4a	3.3a	0.0a	0.0a	0.9a	1.1a	17.7a	58.3a

INTERPRETATION: Cover of crested wheatgrass (Agde) on the CW pastures of HR Land Co. has dropped significantly below that on CW pastures of Wyoming Hereford Ranch; this is reflected in lower production on HR. Range on HR Land Co. is similar in condition to range on the Hirsig ranch but in poorer condition than range on Wyoming Hereford Ranch, which has less bare ground and tends to have more cool-season perennial grasses and less warm-season perennial grasses.

Production of crested wheatgrass, as well as cover, was lower on HR Land Co. than on the Wyoming Hereford Ranch. Production of native range on HR Land Co. was higher than that on the Wyoming Hereford Ranch, which was higher than that on the Hirsig ranch. Use of crested wheatgrass was similar on the HR Land Co. and on WHR, but use of native range was much higher on HR Land Co. than on the other two ranches.

FUTURE PLANS: Monitoring will continue on all three ranches for as long as present management continues. We will request information on stocking rates, grazing seasons and gains from the three landowners, and share our findings with them.

NASTY: NUTRIENT ACCUMULATION NEAR STOCKWATER--TEST OF YIELD

R.H. Hart and G.E. Schuman
Rangeland Resources Research Unit

CRIS: 5409-31630-002-00D

PROBLEM: Increased forage production and shifts in botanical composition of vegetation near stockwater tanks may indicate accumulation of plant nutrients, particularly nitrogen, as a result of increased cattle defecation near water. The accumulated nitrate might leach and raise nitrate concentrations in groundwater to unacceptable levels.

APPROACH: In a preliminary study, small exclosures were placed 10, 20 and 50+ m from stockwater tanks which served 1, 2, 4, 8, or 16 paddocks arranged radially around the tank. It was possible to sample near only 1 tank which served 1 or 16 paddocks (2 sets of exclosures were placed on the latter), 3 which served 2 paddocks, and 2 which served 4 or 8 paddocks. All exclosures except those on the 16-paddock pasture were located on the GRASS experiment; the 16-paddock pasture was located on the HR Land Co. At approximately peak standing crop, herbage was clipped from a 0.2-m^2 quadrat in each exclosure and separated into blue grama (Bogr), western wheatgrass (Pasm), needleandthread (Stco), other grasses, sedges, and forbs and half-shrubs.

FINDINGS: Forage production at peak standing crop was:

Pad-docks	Dist, m	Bogr	Pasm	Stco	Other grass	Sedge	Forbs & shrubs	Total
		-----	-----	-----	-kg/ha-	-----	-----	-----
1	10	188	1033	4	30	307	113	1676
	20	189	532	0	8	235	369	1333
	50+	268	103	98	117	53	120	758
2	10	200	1078	559	30	211	426	2505
	20	309	354	140	83	84	278	1248
	50+	220	155	173	38	58	169	813
4	10	190	115	166	104	48	253	876
	20	123	178	21	116	92	798	1328
	50+	369	117	13	88	45	127	759
8	10	9	3087	203	0	17	161	3478
	20	314	469	200	41	68	122	1214
	50+	214	36	108	223	57	63	701
16	10	156	1369	0	84	0	2340	3948
	20	371	676	0	353	87	181	1668
	50+	552	594	0	118	3	338	1607

Compared to production at 50+ m from water, total forage production and western wheatgrass production increased at 10 m from all tanks except those serving 4 paddocks. Blue grama production decreased around tanks serving 8 or 16 paddocks. Needleandthread increased around tanks serving 2 to 8 paddocks, and forbs and half-shrubs increased around tanks serving 16 paddocks.

INTERPRETATION: Observations were consistent with nitrate accumulation around the water tanks, and suggested greater accumulation as the number of paddocks around the tank increased.

FUTURE PLANS: For the next two years, exclosures will be placed at 10, 20 and 100 m from the water tanks, with 2 replications of each number of paddocks. Only a single pasture is available for a tank serving 1 or 16 pastures; two sets of exclosures will be placed in each of those pastures. Two quadrats will be clipped from each exclosure. Prairie junegrass will be separated from the other grasses, and fringed sagewort from the forbs and half-shrubs.

If technical assistance is available, soil cores will be taken from each exclosure, and total and nitrate N, P and K will be determined; depths of cores will be determined later. Total and nitrate N will be determined on samples of blue grama and western wheatgrass from each exclosure. Other nutrient elements may be determined if labor is available.

MODELLING PLANT AND ANIMAL RESPONSES ON RANGE

R.H. Hart and J.D. Hanson
Rangeland Resources & Great Plains Systems Research Units

CRIS: 5409-31630-002-00D

PROBLEM: Models are needed which are simple enough to run on desk-top computers with inputs readily available to the livestock producer, but complete enough to aid decision-making in livestock management.

APPROACH: The original STEERISK spreadsheet was suitable for semi-arid rangeland with predominantly spring and summer precipitation in the Central Great Plains. We tested the feasibility of re-parameterizing it for other rangeland locations around the western US. Gains and forage intake of steers, over a range of stocking rates, grazing seasons and initial weights, were simulated with SPUR II for locations in Rosebud County, MT; Cherry County, NE; and Sutton County, TX, representing mixed-grass prairie, tallgrass prairie, and desert grassland, respectively. Fifty years of simulations, with appropriate variability of forage production and digestibility, were run for each location x stocking rate x grazing season x initial weight. Equations were developed for each location to reflect the impact of management variables on the parameters of STEERISK.

FINDINGS: We found that very simple equations could describe the impact of management variables on the parameters of STEERISK at each location. Length of grazing season controlled critical grazing pressure (GP), average daily gain (ADG) at the critical GP, and both slope and intercept of the GP x ADG response curve at GP above the critical level. Slope was a function of the reciprocal of length of grazing season; intercept and ADG at the critical GP were linear functions of length of grazing season. Critical GP was calculated as the GP at which the regression line coincided with ADG at the critical GP. Initial weight of steers had a minimal effect on all parameters. Predictions of gains by the reparameterized STEERISK were nearly identical with those by SPUR II; r^2 values were 0.980 for Nebraska, 0.992 for Montana, and 0.997 for Texas.
SPUR II appeared to over-estimate forage production on the Texas site and the influence of forage digestibility on steer intake and gains, and to under-estimate weight loss when little forage was available. Results were presented in an invited paper at the XVII International Grassland Congress and were published in the Proceedings.

Tom Bartlett, Range Science Dept., CSU, requested a copy of the reparameterized STEERISK for each student in his Range Ecosystem Planning class.

FUTURE PLANS: SPUR II simulations of both steer and cow-calf operations will be run for each of the 46 Major Land Resource Areas in which range cattle production is a significant

economic activity. The results will be used to parameterize STEERISK for each of the MLRA's. SPUR II may be modified to reduce the sensitivity of intake and gain to forage digestibility, estimate weight losses when forage is limiting, and provide more realistic estimates of forage production in sites in the Southern Great Plains, or other models may be tried. A wider range of grazing seasons and initial weights will be simulated where appropriate. Results will be published as a USDA publication if approved.

CHEW: CALF HUSBANDRY AFTER EARLY WEANING CREW: COW RESPONSE TO EARLY WEANING

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CRIS: 5409-31630-002-00D

PROBLEM: Calves usually are weaned at 180 to 210 days old, in September or October. By this time amount and quality of forage is so low that weaned calves make little or no gain, and cows are slow to regain any weight lost during nursing. If calves were weaned earlier, any reduction in weight gain below that of unweaned calves might be compensated for by gain of cows, reducing cost of winter feed for cows.

APPROACH: Two 88-ha native range pastures were stocked at 4.00 ha/cow pair (moderate SR), and two 72-ha range pastures at 3.27 ha/cow (heavy SR) from 22 Jun to 21 October 1993. Each pasture contained 18 cow-calf pairs and 4 dry cows. Calves from one pasture at each SR were weaned 24 August at 148-178 days old; calves from the other pasture at each SR were weaned 19 October at 203-255 days old.

Early-weaned calves were held in dry lot and fed good-quality hay for two weeks, then divided into two groups of 18 calves each with equal numbers from each SR. These groups were assigned to two previously ungrazed native range pastures of 10.2 ha each, one with three dry "mentor" cows and one without cows, at 0.57 ha/calf. Cows and calves were weighed every 28 days. Forage production and utilization was estimated as in GRASS, with four exclosures per cow-calf pasture and three exclosures per weaned calf pasture.

FINDINGS: Mean PSC, 13 & 16 August 1993, on CREW and CHEW pastures was 1190 and 1020 kg/ha, respectively. Correlation of meter readings and PSC (r^2) was 0.70. Residual herbage on all 3 studies was measured 22 October 1993; correlation (r^2) between meter readings and residual herbage was 0.93. Utilization on CHEW was 44% and on CREW was 56 and 64% under moderate and heavy stocking, respectively,

Gains were:

Age class	Calves weaned	Stocking rate, Post wean trt	22 Jun-24 Aug	24 Aug-21 Oct	22 Jun-21 Oct
			ADG, kg		
Nursing cows	Aug	Moderate	0.52	0.79	0.65
		Heavy	0.61	0.64	0.63
	Oct	Moderate	0.72	0.08	0.41
		Heavy	0.84	-0.52	0.19
Calves	Aug	Moderate	0.94	--	--
		Heavy	1.12	--	--
		Mentor cows	--	0.13	0.59
		No mentor cows	--	0.25	0.65
	Oct	Moderate	0.93	0.53	0.73
		Heavy	1.15	0.45	0.81
Dry cows	Aug	Moderate	1.03	0.88	0.96
		Heavy	0.94	1.01	0.97
	Oct	Moderate	1.08	0.73	0.91
		Heavy	1.05	0.40	0.74

INTERPRETATION: August-weaned calves gained much less than October-weaned calves from weaning until October. October weaned calves continued to gain, but at less than half the June-August rate. By October, August-weaned calves weighed 188 kg, vs. 210 kg for October-weaned calves, with no significant differences between stocking rates or between weaned calves with or without mentor cows. Cows whose calves were weaned in August continued to gain until October, while cows whose calves were weaned in October just maintained their weight from August to October under moderate stocking, and lost weight (30 kg) under heavy stocking. Increased gain of cows following early weaning was not enough to compensate for the decreased gain of calves.

FUTURE PLANS: This study will be continued for two more years under approximately the same management and stocking rates. A graduate student will observe activity patterns of unweaned and weaned calves and will assist in interpretation of data and preparation of a manuscript, to include economic analysis of the results.

SHAG: SUPPLEMENTING HEIFERS FOR ACCELERATED GROWTH

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Rangeland Resources Research Unit and Animal Science Dept.,
University of Wyoming

CRIS: 5409-31639-002-00D

PROBLEM: For successful calving as 2-year-olds, British-breed heifers should weigh about 300 kg when first bred and 400 kg at delivery of their first calf. If these weights are not achieved, first calving may be delayed, delivery may be difficult, and condition of the heifer may be so reduced that rebreeding for the second calf may be unsuccessful. All these events increase costs and reduce profits.

APPROACH: Two native range pastures of 36 ha each were stocked with 22 yearling heifers each for a stocking rate of 2.64 ha/ head. Pastures were grazed 2 June- 14 October 1993. Heifers on one pasture were supplemented with high-energy blocks containing 15% crude protein. Supplement blocks were supplied in amounts calculated to provide 0.9 kg/head/day, but heifers usually ate more than the allowance when the blocks were first set out, and ran out of supplement before the next blocks were set out. Forage production and supplement consumption were determined; heifers were weighed about every 28 days.

Heifers were exposed to bulls at 15 months of age. Subsequent breeding and calving performance will be related to treatment and gains.

FINDINGS: Mean peak standing crop (PSC) on SHAG was 940 kg/ha; utilization was 71%. Heifers gained 0.61 kg/day without supplement and 0.64 kg/day with supplement; the difference was not significant. Mean weight on 14 October was 360 kg. Calving and rebreeding performance in 1993 did not differ between heifers supplemented or unsupplemented in 1992.

INTERPRETATION: Even though stocking rate and grazing pressure were higher than in 1991 or 1992, supplementation still had no effect on gains. Apparently supplement substituted for forage rather than supplementing it.

FUTURE PLANS: The study will continue for one more year with supplement fed in the same way. Then for two years, the supplemented heifers will have supplement available at all times; supplement consumption will be measured.

RANGELAND RESOURCES RESEARCH UNIT

Publications

Ashby, M.M., R.H. Hart and J.R. Forwood. 1993. Plant community and cattle responses to fifty years of grazing on shortgrass prairie. USDA-ARS Rangel. Resources Res. Unit. RRRU-1.

Booth, D.T. and D.R. Morgan. 1992. Post-germination growth related to time-to-termination for four woody plants. J. Seed Tech. 16:30-38.

Booth, D.T. 1993. Can we improve shrub seedling vigor by managing seed imbibition? p. 47-58. In: Planning, Rehabilitation and Treatment of Disturbed Lands - Sixth Billings Symposium. Reclamation Research Unit Publ. No. 9301, Reclamation Research Unit, Montana State University, Billings, MT.

Booth, D.T. 1993. A possible method for measuring respiration of individual seeds. Soc. Range Manage. #86 (Abstract)

Booth, D.T. 1993. Monitoring respiration of individual seeds during imbibition, germination and early growth. Assoc. of Off. Seed Ann. (Abstract)

Booth, D.T., G.E. Schuman and J.R. Cockrell. 1993. Strategies for establishing Wyoming big sagebrush. Abstracts of Eighth Wildland Shrub Symposium - arid land restoration. p. 30. (Abstract)

Cockrell, J.R., G.E. Schuman, and D.T. Booth. 1993. Strategies for establishing big sagebrush on mined lands. p. 889. In: B.A. Zamora and R.E. Connolly (ed.) The Challenge of Integrating Diverse Perspectives in Reclamation, Proc. 10th Annual Meeting of the Amer. Soc. Surface Mining and Reclamation, Spokane, WA.

Dudley, L.M., W.G. Knight, J.A. Morgan, and H.W. Hunt. 1993. Response of C, N, and P in the root zone of blue grama exposed to elevated CO_2. Agronomy Abstracts, p 225.

Frasier, G.W. 1993. Proceedings: FAO Consultant's Workshop on Water Harvesting, Cairo, Egypt.

Haley, S.D., J.S. Quick, and J.A. Morgan. 1993. Excised-leaf water status evaluation and associations in field-grown winter wheat. Can. J. Plant Sci. 73:55-63.

Hart, R.H. 1993. Viewpoint: "Invisible colleges" and citation clusters in stocking rate research. J. Range Manage. 46:378-382.

Hart, R.H., J. Bissio, M. J. Samuel, and J. W. Waggoner Jr. 1993. Grazing systems, pasture sizes, and cattle grazing behavior, distribution and gains. J. Range Manage. 46:81-87.

Hart, R.H., S. Clapp, and P.S. Test. 1993. Grazing strategies, stocking rates, and frequency and intensity of grazing on western wheatgrass and blue grama. J. Range Manage. 46:122-126.

Hart, R.H., S. Clapp and P.S. Test. 1993. Grazing strategies, stocking rates, and frequency and intensity of grazing. Working Group on Pasture Ecol. Newsl. #31:16-19.

Knight, W.G., J.A. Morgan, W.D. Guenzi, and M.C. Shoop. 1993. Soil-applied atrazine alters blue grama physiology and indirectly influences soil nitrogen. Agron. J. 85:1029-1035.

Latterell, R.L. and C.E. Townsend. 1993. Meiotic analysis of Astragalus cicer L.I. Octploids. Intern. J. Plant Sci. 154(3):450-457.

Lober, R.W. and J.D. Reeder. 1993. Modified waterlogged incubation method for assessing nitrogen mineralization in soils and soil aggregates. Soil Sci. Soc. Am. J. 57:400-403.

Martin, S.S., A.W. Lenssen and C.E. Townsend. 1993. Genetic influence on flavonoid stress metabolite accumulation. Int. Symp. Natural Phenols in Plant Resistance. Friesling-Weihenstephan, Germany. Abstract.

McCaig, T.N. and J.A. Morgan. 1993. Root and shoot dry matter partitioning in near-isogenic wheat lines differing in height. Can. J. Plant Sci. 73:679-689.

Morgan, J.A., D.R. LeCain, T.N. McCaig, and J.S. Quick. 1993. Gas exchange, carbon isotope discrimination, and productivity in winter wheat. Crop Sci. 33:178-186.

Morgan, J.A., D.R. LeCain, and C.E. Townsend. 1993. Carbon isotope discrimination and productivity of falcata alfalfa clones. Proceedings of the XVII International Grassland Congress, New Zealand.

Morgan, J.A., H.W. Hunt, C.A. Monz, and D.R. LeCain. 1993. Consequences of growth at various [CO_2] and temperatures for gas exchange of blue grama (C_4) and western wheatgrass (C_3). Agronomy Abstracts, p. 119.

Morgan, J.A., G. Zerbi, M. Martin, M.Y. Mujahid, and J.S. Quick. 1993. Carbon isotope discrimination and productivity in winter wheat. J. of Agronomy and Crop Sci. 171:289-297.

Read, J.J., and J.A. Morgan. 1993. Growth and carbon partitioning of western wheatgrass (C_3) and blue grama (C_4) as influenced by CO_2 and temperature. Agronomy Abstracts, p 121.

Schuman, G.E. 1993. Soil Restoration. Advances in Soil Science. Vol. 17. R. Lal and B.A. Stewart (ed.) Springer-Verlag, New York. A Book Review. Restoration Ecology 1(2): 139.

Schuman, G.E. 1993. Utilization of sawmill by-products and gypsum to revegetate sodic bentonite mine spoil. p.328. Agronomy Abstracts.

Schuman, G.E., E.J. DePuit, E.M. Taylor, Jr., and J.L. Meining. 1993. Abandoned bentonite spoil reclamation--12 Years of Research. pg. 242-245. In: Planning, Rehabilitation and Treatment of Disturbed Lands, Billings Symposium, Billings, MT.

Schuman, G.E. and J.L. Meining. 1993. Short-term effects of surface applied gypsum on revegetated sodic bentonite spoil. Soil Sci. Soc. of Am. J. 57:1083-1088.

Schuman, G.E., J.D. Reeder, R.A. Bowman, and J.J. Jacobs. 1993. Soil quality and production alternatives of CRP lands in the Central Great Plains. Soil and Water Conservation Society Abstracts

Townsend, C.E. 1993. Breeding, physiology, culture, and utilization of cicer milkvetch. Adv. Agron. 49:253-308.

Townsend, C.E. 1993. Photoperiod-induced dormancy in cicer milkvetch. Agron. J. 85:1146-1150.

Townsend, C.E. and R.L. Ditterline. 1993. Registration of C-18, C-19, C-20, and C-21 germplasms of cicer milkvetch. Crop Sci. 33:649.

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MISSION STATEMENT

To develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality, and sustain long-term productivity.

TECHNOLOGY TRANSFER - 1993

Soil-Plant-Nutrient Research Unit

The Soil-Plant-Nutrient (SPN) Research Unit continues to contribute to N-management technology transfer to the Soil Conservation Service and other USDA agencies. This has been done by planning and commencing to write up information for development of the 1995 Resource Conservation Act (RCA) report to congress and by working with NPS to identify other ARS scientists nationally to assist. In addition, SPN scientists have worked with the USDA Global Change Office to develop the N-section for the President's global change action plan. Within Colorado, a joint SCS-ARS research program has been initiated in the San Luis valley to calibrate and extend the use of the NLEAP model for seven crops farmer fields and to help develop BMPs for that farming area. Initial planning has also been done with Longmont Foods Inc. on possible research using composted Turkey waste materials. An initial understanding to allow SPN Scientists to obtain samples of high nitrate waters from the Rocky Mountain Arsenal is providing additional samples for testing of a static bioreactor that uses innocuous vegetable oil as a carbon source. The static bioreactor has been developed by SPN scientists and is being submitted for consideration to be patented. The Chisso Company Ltd. (in Japan) has requested help and is providing material for SPN scientists to test a polyolefin coated urea (POCU). The POCU is a delayed release N-fertilizer that my improve fertilizer-N use efficiency by better timing the availability of the N to the needs of the crop.

SOIL NITROGEN TRANSFORMATIONS AND THEIR ROLE IN NITROGEN USE EFFICIENCY AND C AND N TRACE GAS FLUXES THAT CONTRIBUTE TO GLOBAL CHANGE

Arvin R. Mosier, Jorge A. Delgado[1] & David W. Valentine[2]
Soil-Plant Nutrient Research Unit

CRIS: 5402-12130-002-00D

I. MAINTAIN QUALITY OF WATER AND THE ENVIRONMENT THROUGH IMPROVED NITROGEN USE EFFICIENCY.

PROBLEM: Efficient use of N fertilizers is minimized in many agricultural systems because of the loss of large amounts of the applied N through nitrate leaching, by ammonia volatilization or by denitrification. A key to limiting all of these loss process is to maintain mineral N concentrations in the soil as low as possible throughout the year. Since N fertilization is required to maintain crop production, N can be applied frequently through the cropping season, nitrification inhibitors can be used, or control release fertilizers can be applied to minimize nitrate accumulation. Frequent N applications in most cropping systems adds cost and is impractical, nitrification inhibitors can be functional but most have serious limitations. Generally the easiest method of fertilizer application is at crop planting. Using controlled-release fertilizers at planting is a potential mechanism of providing N to meet crop demand while limiting accumulation of nitrate in the soil. Chisso Company Ltd in Japan has developed a polyolefin coated urea (POCU) which shows some promise as an effective control-release N fertilizer. Helena Chemical Company markets the material in the U.S. We initiated a series of field studies to test the ability of POCU to provide adequate N for the crop, to limit soil nitrate accumulation, to decrease N_2O emissions due to fertilizer application, and to improve N-use efficiency.

APPROACH: A variety of polyolefin coatings (trade name Meister) are available from Helena Chemical Company, Memphis Tennessee, for urea to provide release of urea to meet crop demand. The urea release rate is based on soil temperature. A field study was conducted at the Colorado State University Horticultural farm to compare N-use efficiency of urea, urea plus the nitrification inhibitor dicyandiamide (DCD), and Meister 7 in irrigated spring barley. The study was designed to compare the effects of the different treatments (applied at planting) on nitrate leaching, crop use, and soil-atmosphere exchange of N_2O, CH_4 and CO_2. In addition to the Meister, Helena Chemical provided enough ^{15}N-labeled Meister so that ^{15}N-labeled fertilizer could be used to track the fate of applied N in the system in each treatment. A second study

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[1]ARS Post Doctoral Fellow.

[2]U.S. Department of Energy, Global Change Distinguished Fellow until November 1, 1993. Currently at the Natural Resource Ecology Laboratory, Colorado State University

was initiated in September, 1993, comparing the effect of Meister 15, urea plus DCD, and urea, on N use efficiency, nitrate leaching, crop use, and the soil-atmosphere exchange of N_2O, CO_2, and CH_4 in winter wheat. ^{15}N-labeled Meister 15 and urea was also used in this study.

FINDINGS: The analyses of soils and plants for N and ^{15}N content for the barley experiment have not been completed. Barley yield was increased 31, 48 and 57% for Meister 7, urea, and urea + DCD, respectively compared to unfertilized controls. Nitrous oxide emissions were lowest throughout the barley cropping season from urea + DCD plots. Meister 7 released urea throughout the crop growth period but maintained sufficient nitrate in the soil to increase N_2O emissions near the end of the barley growth period compared to urea and urea + DCD treatments. Early in the season N_2O emissions were larger from the urea treatment compared to all other treatments. Methane fluxes were not affected by any of the fertilizer or inhibitor treatments. The wheat study was begun in September, 1993 and an initial response to N-fertilizer treatments was observed for N_2O and CH_4 fluxes during the months of September and October similar to the initial fluxes observed in the spring barley. The study will be completed in September, 1994.

FUTURE PLANS: All of the analyses required to finish the wheat study will not be complete until the end of 1994. Future studies with Meister will depend upon the preliminary results of both the barley and wheat studies currently in progress.

II. ASSESS, PREDICT AND MITIGATE AGRICULTURAL C AND N TRACE GAS FLUXES THAT CONTRIBUTE TO GLOBAL CHANGE

CRIS: 5402-11000-004-00D, 5402-11000-004-05S, 5402-11000-004-06S

PROBLEM: It is generally agreed that if the trends of increasing atmospheric concentrations of CO_2, CH_4 and N_2O continue, that mean global atmospheric temperature will rise two to six °C during the next century. Such a global temperature change would cause a rise in the oceans, possibly change precipitation patterns, and alter agricultural production. Soils have a major impact on changes of atmospheric concentrations of these gases. A general recommendation from a number of international conferences was that intensive studies be made about conditions leading to the soil-atmosphere exchange of these gases and their relative source/sink relationships. The aim of such studies should be to create the necessary scientific basis for improved land management practices to limit emissions or increase sinks while maintaining soil productivity.

APPROACH: A field program was begun in 1990 to monitor N_2O, CH_4, and CO_2 soil-atmosphere exchange, year around, from 7 sites in the Central Plains Experimental Range (CPER) (A). Since that time 8 different sites at CPER, sites in grasslands in Puerto Rico (B), subalpine forest (C), a mountain meadow and agricultural systems (D & E) have been established. See the 1990 annual report for methodology. In addition to flux measurements, a number of soil

physical and chemical parameters are measured. These monitoring efforts lay the basis for developing process-based flux models for CH_4 and N_2O (G).

FINDINGS: (A) Studies at the CPER continue to demonstrate that N fertilization and cultivation decrease the rate of soil oxidation of atmospheric CH_4 and increase the rate of emission of N_2O. The general trend for this semiarid shortgrass steppe is for CH_4 consumption to decrease with increased agricultural intensity and N_2O production to increase. Plowing the native grassland resulted in decreased CH_4 consumption and increased N_2O emission through the year. These studies, along with the others that follow demonstrate the necessity to measure gas fluxes all year, not just during the growing season.

(B) After a year of monitoring N_2O and CH_4 fluxes in three fertilized and nonfertilized grassland sites in western Puerto we found that CH_4 consumption in these tropical soils was not decreased by N fertilization. Nitrous oxide emissions were increased by N fertilization but emissions were lower than expected when compared to grasslands in Costa Rica. The effect of plowing on gas fluxes was measured at the Isabela, oxisol, site only. Unlike the short grass steppe in Colorado, plowing had no lasting effect on either CH_4 or N_2O flux.

(C) The cooperative study with the USDA/Forest Service of trace gas fluxes in subalpine forest systems continued through 1993. These studies revealed that soils continue to produce CO_2 and N_2O and consume CH_4 during the snow covered time of the year. Such systems were previously considered to play little role in the global biosphere-atmosphere exchange of these gases during the winter time. The average N_2O flux during the snow-free time was 1.9 ug N m^{-2} hr^{-1} and 1.0 ug N m^{-2} hr^{-1} during the snow-covered part of the year. Methane flux averaged -12.5 ug C m^{-2} hr^{-1} during the snow-free part of the year and -3.4 ug C m^{-2} hr^{-1} during the snow-covered part of the year.

(D) ^{15}N-labeled urea or ammonium nitrate was applied to microplots in the Wyoming irrigated mountain meadow research site, both in the autumn of 1992 and spring of 1993 to determine the fate of applied N. These microplots were destructively sampled following forage harvest in August, 1993. The samples were returned to Ft. Collins and frozen for later analyses. Gas flux sampling continued from the time of snow-melt until forage harvest. The general trends of greater N_2O emissions from ammonium nitrate fertilization observed in 1992 were also found in 1993. Methane flux was not influenced by either autumn or spring N-fertilization.

(E) Weekly gas flux monitoring was begun in the Sidney Nebraska long-term tillage site in March, 1993 and continued through the year. Methane consumption rates generally trend sod > notill > subtill > plow when tillage treatments are compared. The general trend for N_2O emissions appears to be plow > subtill > notill > sod. More data collection and complete data analyses are needed before system evaluation can be completed.

(F) In 1981 a set of long term ^{15}N studies were initiated on a catena at the CPER. A detailed analysis of ^{15}N-labeled soil profiles is being completed. These analyses confirm that the

short-grass steppe is a nitrogen conserving system. N losses after the first year following N application, based on ^{15}N analyses, are small.

(G) Using the data generated from the CPER studies David Valentine, Bill Parton and Dennis Ojima of the Colorado State University, Natural Resource Ecology Laboratory have developed first generation models to describe soil CH_4 consumption and second generation models to describe N_2O production. The CH_4 uptake model link uptake rate to soil temperature and moisture, gas diffusion rates and concentration gradients, and biological demand. The models are structured so that they may be readily generalized and extended across soil types and biomes. The N_2O model describes the nitrification and denitrification production processes in terms of soil moisture, substrate, and temperature variables that we quantify at each study site.

FUTURE PLANS: (A) Intensive gas flux monitoring will continue at the CPER through 1994.

(B) Intensive gas flux monitoring will continue at the three sites in Puerto Rico through 1994. In addition, new sites have been established on acid soils, looking at plowed and non-plowed 5 year old pastures and in a sorghum field in the Isabela oxisol. Additionally, during 1994, denitrification studies will be conducted at each site and, if time and funding permits ^{15}N fertilizer N loss studies will be established at each of the pasture sites.

(C) The cooperative studies with the USDA/Forest Service at the Glacier Lakes Experimental Ecosystem will continue through the snow covered period of 1994. Personnel and resource limitations will probably not permit continuing the gas flux studies through the snow-free part of 1994.

(D) Gas flux studies in the irrigated mountain meadow site will not be performed in 1994. The analyses of soils and plant material for N and ^{15}N in the studies conducted during 1992 and 1993 will be completed before the end of 1994 and a manuscript describing the results of these studies will be written.

(E) Gas flux and ancillary data collection will continue at least through September, 1994.
(F) A manuscript describing the results of the long term ^{15}N study at the CPER is currently being prepared and should be completed early in 1994.

(G) The CH_4 uptake models and N_2O emission models for CPER will be completed. These models will then be used to describe gas fluxes in our other study sites. Laboratory and field studies will be initiated to parametrize the models so that they are generally applicable to the variety of biomes in which studies have been conducted. The models will then be adapted to more general ecosystem applications.

NO_x, N_2O, AND CH_4 EXCHANGE DURING N TRANSFORMATIONS IN SOIL

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CRIS: 5402-11000-004-00D and 5402-11000-004-03S

PROBLEM: Gaseous N oxides, N_2O and NO_x ($NO+NO_2$), are radiatively, chemically, and ecologically important trace atmospheric constituents. N_2O absorbs outgoing planetary infrared radiation with wavelengths not removed by atmospheric CO_2 or H_2O, thereby contributing about 5% of the overall anthropogenic greenhouse effect. Because it is chemically inert in the troposphere, N_2O is readily transported upward to the stratosphere where it is also involved in destruction of the O_3 that protects life forms on Earth from incoming solar ultraviolet radiation. Conversely, NO_x has no direct effects on the planetary radiation balance, but is chemically very active. It plays a critical role in establishing the abundance of tropospheric oxidants, including O_3 (which is radiatively active) and OH radical (which is involved in the photochemical removal of atmospheric CH_4, another greenhouse gas with rapidly increasing concentration). Eventually, NO_x is itself photochemically oxidized to HNO_3, the fastest growing component of acidic deposition. Among other ecologically important functions of gaseous N oxides, the emission, transport, and subsequent redeposition of NO_x accomplishes substantial N redistribution both within and among natural and disturbed ecosystems, thereby influencing their productivity and N use efficiency. Microbial processes in soil is a major source of atmospheric N oxides and represents both a source and sink for atmospheric CH_4, so it is important to understand the exchange of these gases across the soil-atmosphere boundary and, if appropriate, to develop mitigation technologies.

APPROACH: Short-term soil emission of gaseous N oxides has recently been measured from several different ecosystem types under a variety of soil and climatic conditions around the world. Conspicuously absent from the literature, however, are comprehensive longer-term studies that yield tenable estimates of total annual N_2O, and particularly NO_x, evolution from any particular site. Further extrapolating existing data to assess the overall contribution of soil N oxide emissions to the global atmospheric N_2O and NO_x budgets is also confounded by the apparent existence of multiple biotic and abiotic sources of the gases, each of which is subject to a different set of controllers. Recent data suggest that N transformations in soil also interact with CH_4 uptake, but the relative contributions of specific microbial processes remain to be determined. Overall objectives of my research are (1) to establish the magnitude and direction of annual soil and foliar gaseous NO_x exchange in a variety of agronomically- and environmentally-important situations, (2) to determine the relation of NO_x to N_2O and CH_4 exchange rates in each situation, (3) to identify and characterize major controllers of the biotic and abiotic processes responsible for these exchanges, and (4) to assess the importance of the exchanges to crop productivity, N use efficiency, and ecological/environmental issues of current public and scientific concern. Procedures for laboratory soil incubation studies conducted to examine processes and pathways were summarized in a recent publication. Methods for field

monitoring of NO_x, N_2O, and CH_4 exchange and for field testing of laboratory findings have been summarized in previous reports.

FINDINGS: In continuing small plot research conducted in cooperation with personnel at the Central Great Plains Research Station (Akron, CO) the observed variability in soil NO and N_2O exchange rates was successfully simulated by the product of a constant that reflected soil N availability, an exponential function of soil temperature, and a dual-slope linear function of soil water-filled pore space. Ten- to fifty-fold differences between fluxes measured under widely-divergent conditions were reduced to less than a factor of two after normalization to the same soil temperature and water content, and the remaining differences were correlated with measured changes in various soil N availability indices. On one spring and one fall sampling date, intensive sampling was scheduled to coincide with simultaneous measurement of various soil quality parameters by Dr. J.W. Doran. Objectives of the simultaneous measurements were (1) intercomparison of methods, and (2) to determine the potential value of his selected soil quality indicators as predictors of soil gaseous N oxide and/or CH_4 exchange.

In laboratory soil incubation experiments, soil emission of both NO and N_2O increased substantially with decreasing O_2. NO exceeded N_2O emission at all O_2 concentrations, regardless whether C substrate or a nitrifcation inhibitor (nitrapyrin) was added. At 21% O_2, the principal effect of added C was to reduce NO and N_2O emission by immobilizing ammonium; at 0.0% O_2, C enhanced the rate of denitrification-based emissions by stimulating heterotrophic growth; at intermediate O_2 concentrations, C's primary effect resulted from its reduction of O_2 availability. By comparing the results obtained in the presence and absence of nitrapyrin, we determined that autotrophic nitrifiers were the primary source of NO and N_2O at O_2 concentrations greater than 2%, and heterotrophic organisms were the primary source at concentrations less than 0.2% O_2. The ($NO+N_2O$) yield of nitrification increased with declining O_2 supply, probably because N_2O (and maybe some of the NO) was produced by reduction of product nitrite, which increased as O_2 became limiting. The yield of heterotrophic denitrification was much higher, but tended to decrease at lowest O_2 availability, probably because N_2 became an increasingly important product.

INTERPRETATION: Although the proposed model provided a good fit to observed rates of NO and N_2O emission from the Conservation Reserve plots at Akron, better understanding of the model constant's dependence on the sizes/transformation rates of identifiable soil N pools and an effective method of adjusting the effect of wetting for existing soil water content are needed before this approach can be extended over larger areal and temporal domains. Results of the laboratory soil incubation study contribute to separating and identifying the confounded influences of soil water content, O_2 concentration, and soil gas diffusion rates on the production and consumption of NO_x and N_2O by various microbial groups in soil. In addition, this year marked the completion of comprehensive review articles regarding (1) the use of enclosure systems for measuring trace gas fluxes from soil and water, (2) recent advances in our understanding of the biogeochemical controllers of NO_x and N_2O production, consumption, and transport in soil at both cellular and field/landscape scales, and (3) a summary of N cycle interactions with global change processes. Livingston and Hutchinson (1994) was probably the most significant of the reviews because of its comprehensiveness and the interdisciplinary importance of its topic. The most notable contribution of the other reviews is that they

synthesized the complex biology of soil N oxide exchange in a form understandable by physical scientists, and the tangled atmospheric chemistry of the gases in language available to biological scientists.

FUTURE PLANS: Because results from the field demonstrated the need for long-term measurement of soil trace gas exchange and for using simulation modeling to better understand net N oxide and CH_4 production and transport, we plan to continue measurements of NO_x, N_2O, and CH_4 exchange from N-fertilized and unfertilized grass, no-till, and conventionally-tilled CRP plots at the Akron field station. The primary objective of this effort is to improve and validate a proposed process-level model that describes the contributions of several microbial processes to the measured exchange of NO_x, N_2O, and CH_4 in terms of easily-measured biological and geochemical parameters that have potential as predictors of the emission rates at other cultivated and grassland sites. In addition I will (1) continue laboratory soil incubation studies to determine the effect of O_2 availability on the relative contributions of nitrification and denitrification to soil NO_x and N_2O exchange in accordance with the terms of Specific Cooperative Agreement No. 58-5402-1-102, (2) complete summarization and publication of the results from previous cooperative studies with Prairie View A&M University, (3) complete preparation of an article for the Journal of Geophysical Research describing a statistically-testable diffusion-based trace gas flux model for non-steady-state chamber concentration data, and (4) complete data accumulation and summarization of basic research examining the interactions of soil N cycling with microbially- mediated soil CH_4 exchange in sub-humid and semi-arid climates. The latter objective will be conducted in cooperation with Dr. G.P. Livingston from NASA's Ames Research Center in Moffett Field, CA, a visiting scientist in my laboratory from December 1993 through May 1994.

N-15 RECOVERY IN A WHEAT-SORGHUM-FALLOW-WHEAT ROTATION UNDER NO-TILL IN THE SEMIARID CENTRAL GREAT PLAINS

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CRIS: 5402-12130-001-00D

PROBLEM: Agricultural production and concerns for water quality, sustainability and economic viability in the agricultural community are linked to fertilizer N-use. The predominate cropping system of the semiarid Central Great Plains has been the winter wheat-fallow system under stubble mulch cultivation. This system has been successful because plant available water is highly variable and limiting and the fallow period stores in the soil an average of 5.13 cm of water. Herbicides for weed control and improve machinery for planting into standing stubble have made possible the adoption of no-till cropping in this region. The no-till cropping increases soil moisture storage and thus provides the opportunity to successfully grow spring planted crops like sorghum, corn, and millet in rotation with the winter wheat. However, the additional cropping requires additional nitrogen inputs to maintain sustainable yields. Information on fertilizer N movement, carryover and N-use efficiency in a no-till rotation in this semiarid region is needed.

APPROACH: A no-till wheat-sorghum-fallow rotation study at the Central Great Plains Research Station, Akron CO was established in 1987 to determine: (1) NO_3 carryover and movement in profile, (2) the uptake or utilization of indigenous soil N and tagged fertilizer N by the crops, (3) the movement of or release of N from crop residues, (4) the changes in size and incorporation of fertilizer N into the microbial biomass. Our approach was to fertilize microplots at different time in the rotation with two rates, 56 and 112 kg N/ha, of $K^{15}NO_3$, transfer labeled residue to non-labeled plots, and seasonally measure labeled N plant uptake, nitrate distribution in the soil profile, and labeled N transferred into the biomass.

FINDINGS and INTERPRETATIONS: In the rotation of wheat-sorghum-fallow-wheat, if only the first wheat crop was fertilized with tagged N the total plant recovery of tagged N by the three crops was 70 and 63 percent for the fertilizer rates of 56 and 112 kg^{115}N/ha respectively. Tagged N remaining in the soil amounted to 26.7 and 24.3 percent of the applied N for the 56 and 112 kg^{15}N/ha respectively. Total labeled N accounted for after 4 years was 96.7 and 87.3 percent for the respective fertilizer treatments. The sorghum crop recovered 13.9 and 15.6 percent of the ^{15}N applied to the prior wheat crop and the final wheat crop recovered an additional 4.6 and 5.6 percent for the 56 and 112 kg^{15}N/ha rates respectively. Where both the wheat and the sorghum were fertilized with ^{15}N, total plant recovery rotation was 65.1 and 57.7 percent and tagged N in the soil was 27.7 and 23.4 giving total balance of 92.8 and 81.1 percent for the 56 and 112 kg^{15}N/ha rates respectively. Carry over into the second wheat crop was 6.1 and 8 percent of the applied N for the respective fertilizer rates of 56 and 112 kg^{15}N/ha. When only the sorghum crop was fertilized with labeled N the recovery for the sorghum and wheat crop

was 69.6 and 55.8 percent for the 56 and 112 kg ^{15}N treatments respectively and 24.4 and 23.5 percent of the tagged N remained in the soil giving a total balance of 94 and 79.3 percent of the applied N. Seven and 14 kg^{15}N/ha were contained in the chaff and wheat-straw for the 56 and 112 kg ^{15}N/ha treatments. When this residue was traded with non-labeled plots it released approximately 12 percent of its tagged N to the sorghum crop and 12 percent to the next wheat crop, i.e. 24 percent of the tagged N in residue was available to subsequent crops in the rotation.

Nitrogen use efficient was greatest at the 56 kg^{15}N/ha rate. The higher fertilizer N rate was 10 to 15 percent less efficient than the lower N rate. The 90 percent plus balance for soil plus crop N indicates that less than 10 percent of the applied N is being lost from the rotation at the 56 kg N/ha fertilizer N rates.

FUTURE PLANS: The plan is to continue data analyses and manuscript preparation.

NITRATE LEACHING AND PLANT UPTAKE IN FURROW IRRIGATION

Joe Benjamin, L. K. Porter and Harold Duke

FUTURE PLANS: In cooperative study in the spring of 1994 we will initiate a nitrate leaching and plant uptake experiment in a furrow irrigation system utilizing ^{N14}N and ^{15}N fertilizer. The objective of the study is to determine fertilizer N uptake by corn and nitrate leaching patterns from band applications of nitrogen fertilizer where fertilizer is place in non-irrigated and irrigated furrows and where the irrigation is alternate and every row furrow.

ISOLATION OF CELLULOLYTIC/N_2-FIXING ORGANISMS

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CRIS: 5402-12130-001-00D

PROBLEM: Cellulose is the most abundant organic chemical in nature with an annual production of about $7.5*10^{10}$ tons. It is difficult to decompose, no organisms higher than fungi possess enzymes capable of cellulose degradation. It contains no nitrogen and is usually found in plant materials and products (such as paper) that have low nitrogen content; thus nitrogen deficiency often limits growth of organisms able to decompose cellulose.

Cellulose products make up more than half of the materials entering U.S. municipal landfills. Current projections are that landfill tipping fees will soon exceed $100/ton in many areas and that the amount of cellulosic wastes to be disposed of will rise to 10^8 tons/year. In addition, many agricultural and food-processing wastes are composed primarily of cellulose. Burning has traditionally been used to dispose of residues such as straw and sugarcane residue that inhibit the growth of the subsequent crop if not removed, but this practice is being curtailed by law in many locations. In all of these cases, composting the cellulose waste materials may be a viable option. Microorganisms that could fix nitrogen from the air using energy from cellulose decomposition could potentially speed the process and increase the nitrogen content (thus the value) of the final product. Both of these factors could have potentially great impact on the economics of composting cellulose waste. Composted waste could potentially be used as a mulch/fertilizer or as an animal feed.

APPROACH: The main thrust of the project is measure N gain and mass loss in microbial cultures grown on cellulose medium under oxygen levels ranging from atmospheric to anaerobic. This will give a quantitative measure of the N_2-fixing and cellulose-degrading abilities of each culture. A range of oxygen levels will be used because oxygen level strongly influences nitrogen fixation (oxygen inhibits nitrogenase, the enzyme that carries out the first step in fixation) as well as cellulose degradation. Also, oxygen levels in composting systems are always lower than atmospheric, thus reduced-oxygen conditions are appropriate for screening microorganisms for use in composing. A large number of cultures will be screened in this way, including isolated (purified) organisms capable of growing on N-deficient cellulose agar, microbial communities sampled from a wide range of natural locations and composting facilities, and cultures that the scientific literature indicates are promising that we are able to obtain from other researchers or culture collections.

The cultures that are found to give the greatest N gains when grown on cellulose medium will be further characterized with regard to their N_2-fixing abilities using acetylene reduction and ^{15}N-uptake techniques. Ability to reduce acetylene is taken as evidence of the presence of the nitrogenase enzyme, which can use acetylene as an alternate substrate to N_2. Uptake of ^{15}N is generally regarded as the only positive proof of N_2 fixation.

RESULTS: A substantial survey of the scientific literature regarding simultaneous cellulose degradation and N_2 fixation has been completed. Knowledge thus gained has been used in refining the experimental approach.

Over one hundred microorganisms, primarily bacteria, have been isolated that are capable of growth on N-deficient cellulose agar. Approximately twenty of these have been tested for ability to reduce acetylene, of which two tested positive in the absence of oxygen. None tested positive at atmospheric oxygen levels.

An experiment to choose the type of cellulose medium to use in the screening experiments is nearly completed. Thirty-six different cellulose-based media were tested. This experiment also compared two fundamentally different ways of measuring the N content of microbial cultures and refined each method to maximize it suitability for the screening experiments.

Capability to collect weight data from a balance directly on a computer has been developed to assist with measuring mass loss on large numbers of cultures. A system has been designed to maintain the cultures at constant temperature and under six different oxygen levels, and all equipment need for this system has been obtained or ordered. This system is of sufficient size to allow the screening of 132 cultures (all at six different oxygen levels) simultaneously. Because this system involves use of partial vacuum, an experiment to test the effect of partial vacuum on a range of microorganisms was carried out simultaneously with the media experiment.

FUTURE PLANS: Construction of the system for maintaining six different oxygen levels will begin shortly. Once constructed, the first screening experiment will be initiated in which N gain and mass loss will be measured. Promising cultures will be replicated in subsequent screening tests to determine reproducibility of results. These experiments will be conducted both at 30 and 50°C. Cultures that reproducibly give the highest N gains will be characterized further with acetylene reduction, and ^{15}N fixation techniques. If they are pure cultures, we will attempt to classify the microorganisms; if they are mixed cultures, we will attempt to isolate the individual members and reconstitute an effective culture from isotates. If promising organisms are identified and time permits, the organisms will be cultured using actual cellulose waste as substrate. This could be done in the laboratory in the same manner as the screening experiments. Also, composting experiments could be performed by inoculating mesh bags of starting material (cellulose waste) with the desired microorganism and then letting them go through the composting procedure.

A collection trip is planned to sample a number of natural environments and composting facilities in which highly active cellulolytic/N_2-fixing organisms or communities would plausibly be found. Currently an experiment is underway to determine the most suitable way to store samples to preserve microbes in a culturable state.

GROUND-WATER NITRATE

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San Luis Valley Water Quality Demonstration Project (SCS).

CRIS: 5402-12130-001-00D and 0500-00026-016-00D

PROBLEM: Managing nitrogen (N) for ground water quality is of increasing national concern among the general public and within the agricultural community. Within Colorado, an important agricultural region that has high ground-water nitrate levels is the San Luis Valley (SLV). The San Luis Valley has a combination of course textured soils, high water tables, and production of high N requiring crops. Nitrate-N levels as high as 75 ppm have been detected at the surface of the water table. A strong aerial correlation exists between center-pivot irrigation, cropping, and ground-water nitrate levels. In December 1992, the Soil Conservation Service formally requested technical assistance for their SLV Water-Quality Demonstration Project from the Soil-Plant-Nutrient Research Unit.

APPROACH: By spring, 1992, joint planning with SCS personnel at both the CO state office and field levels was done, including selection of field experimental sites. Project goals are to use the NLEAP (Nitrate Leaching and Economic Analysis Package) model in concert with the SCS-SLV project to: a) assess how current farm management practices in the valley impact ground-water nitrate contamination, b) develop and evaluate alternative management practices to decrease ground- water nitrate contamination, and c) develop a valley-based customized NLEAP package for SCS Area and Field office use. To address these project goals, year 1 objectives were:

Objective 1. <u>Model calibration</u> - Two field sites, with varying soil textures, were selected and have been sampled to begin configuring NLEAP to measured residual nitrate levels.

Objective 2. <u>Determine N-uptake indices for selected crops grown in the SLV</u> - Selected crops, which are either currently grown or are anticipated crops in the future are being analyzed to determine N uptake, a parameter required by NLEAP:

- a. 4 varieties of potato
- b. Head lettuce
- c. Barley
- d. Canola
- e. Oats
- f. Winter Wheat
- g. Crambe

Objective 3. <u>Evaluation of nitrate loss under various management practices using NLEAP</u> -

Three statistically replicated studies have been initiated:

a. Two adjacent fields having different N management, under potato. Both use pre-plant banding, but one uses broadcast at dragoff plus 2 additional pivot applications. The other uses only pivot application, but applies N more frequently.

b. Nitrate leaching under a potato-small grain rotation. Two years of potato followed by barley is a common rotation. This study will evaluate the magnitude of leaching under all three crops in the sequence.

c. Effect of different N-rates on nitrate leaching under barley following a cover crop of winter rye. N-rates include 0, 20, 40, and 60 # N/ac plus an additional 30 # N/ac to all treatment at the barley 2-3 leaf stage.

Objective 4. <u>Evaluation of winter-wheat nitrate loss on soils with contrasting particle size classes</u> - Preliminary NLEAP simulations indicate a significant nitrate leaching event in the SLV with snow melt in the spring. This statistical study will evaluate winter/ spring nitrate leaching of two soils with contrasting particle classes and water holding capacities located in one field.

FINDINGS: All sampling has been completed for the summer field season efforts.

a. Spring soil samples have been analyzed and compiled.

b. Fall crop and soil samples have been collected and are currently being processed and analyzed.

c. Soil sample analyses for a 5 ft. depth at 1 ft. increments include: NH_4, NO_3, $\%H_2O$, Particle size, $\%CaCO_3$, SAR, EC, pH, %OM, and dry sieve analysis for >2mm fractions.

Collection of temperature and precipitation on the winter wheat study by the SCS Water-Quality Demonstration Office will be continued throughout the winter/spring.

Over the winter, NLEAP simulations will be run on the studies above and compared to field measurements. Also, alternate management strategies, which appear feasible, will be simulated with NLEAP for demonstration purposes.

Cooperative planning with the ARS - Great Plains Systems Research Unit scientists will be ongoing including generating GIS regional maps using NLEAP to obtain simulation output of alternative management strategies that might be feasible.

INTERPRETATION: Effective N-, irrigation, and crop-management is necessary in the SLV to prevent leaching of nitrates into the ground water. After NLEAP calibration and correlations of predicted and observed amounts of residual soil nitrate (RSN) levels, this study should allow alternative management and cropping to be designed to decrease leaching of nitrate into ground water in the SLV. With adequate field testing and adoption of these improved systems, water quality improvements should be possible.

FUTURE PLANS: Future plans are to continue sample collection for at least one more year; including sample analyses, data compilation, and NLEAP assessment to determine the months and cropping management systems most vulnerable to N-leaching below the crop root zone as it may assist in evaluation of potential BMP's.

DRYLAND CROPPING SYSTEMS

R.F. Follett, L.K. Porter and A.D. Halvorson
Soil-Plant-Nutrient Research Unit and

CRIS: 5402-12130-001-00D

PROBLEM: It is projected that between 60 and 70 percent of all US cropland will be farmed with some type of conservation tillage by the year 2000. Tillage systems influence soil properties, N-use efficiency, and nitrate leaching. Consequences of widespread adoption of reduced-tillage practices on Great Plains soils is not adequately understood. Also not adequately understood are the consequences of long-term tillage on N-use efficiency and nitrate leaching in the Great Plains. Our objective is to determine N-pool sizes, seasonal or annual N-movement rates among various pools, and N-transformation processes in a wheat, sorghum (corn), fallow rotation.

APPROACH: A no-till dryland cropping rotation (winter-wheat, sorghum, fallow, winter wheat) study was initiated at Akron, CO. The approach was: (1) to utilize ^{15}N isotope to study uptake of fertilizer-N versus soil N into growing crops, (2) to utilize isotopically labeled crop residues to study crop residue N movement into the subsequent crop(s), into microbial biomass, and/or active versus stabilized soil-N pools, and (3) to measure the movement of ^{15}N isotope from organic matter and fertilizer pools into a leachable mineral pool that has moved below the bottom of the crop root zone.

Much of the analyses is either completed or being done. Plant samples were collected at boot, heading, and mature growth stages. Soil samples to a 150 cm depth, at 30 cm intervals were collected before and after harvest, and 10 cm depth samples were collected to correspond with plant growth stages for determining microbial biomass. These samples are mostly analyzed for ^{15}N, total N, and dry matter, and microbial biomass accumulation. N-uptake and N-utilization from normal abundance KNO_3-N and KNO_3-^{15}N fertilizer, applied in 1988 and 1989 is being assessed. The cropping sequence has been a wheat-sorghum-fallow-wheat-corn-fallow rotation.

RESULTS and INTERPRETATION: During the first crop year of this no-till rotation study, the relative percent (NPER) of soil-N derived from fertilizer (Ndff) in the top 4 inches of soil relative to that found in the top 4 feet decreased significantly. Then, during the 2nd and into the 3rd crop years, NPER increased significantly. This process, whereby crops grown using no-till can, in subsequent years, concentrate the remaining Ndff in the soil back near the soil surface helps conserve the N from leaching and places it in the most biologically active region of the crop root-zone. Within the top 4 inches of soil, microbial biomass-C and -N ranged from about 290 to 560 and 60 to 100 mg kg^{-1} of soil, respectively. Apparently, crop residue produced during the 1st and 2nd years provided sufficient C to the soil for maximum levels of biomass-C and -N to occur during the 3rd, fallow, year. Concentration of ^{15}N in microbial biomass continued to increase through the 4th year, even though applied only to the 1st or 2nd crop. Thus, microbial biomass appears to contribute to the conservation of Ndff for a long time after

the fertilizer N is applied. Use of fertilizer-^{15}N tracer to determine movement of fertilizer in the soil profile indicates there was essentially no leaching and most of the fertilizer N staying within the root-zone.

FUTURE PLANS: The plan is to now go into a longer-term observation phase for the field plots and to move ahead with data analyses and interpretation.

AMMONIA EMISSION FROM SOYBEAN RESIDUE DECOMPOSITION

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM: Ammonia (NH_3) may be the most important of the nitrogen (N) gases exchanging with the earth's surface in N-budget measurements between earth and atmosphere. Decay of crop residues is a major source of the N that potentially contributes to exchange of NH_3 between cropland soils and the atmosphere. When crop residues, especially legumes, are returned to the land as green manure, even larger amounts of NH_3 per unit of land area would be expected to evolve. In the United States, about 3,000 Gg of N are returned to cropland soil in crop residues each year; of which soybean residues alone account for about 23 percent.

Currently, there are few studies of NH_3 evolution from the decay of crop residues. The relative importance and interactions of factors affecting decomposition of crop residues and their contributions to NH_3 exchange to the atmosphere are likely quite complex. Our objective was to assess the importance of soil temperature, soil moisture, and crop residue addition rates on NH_3 losses from soybean residue amended soil.

APPROACH: Soil was a Weld silt loam. Soybean tissue and soil were mixed to obtain 5 or 2.5% by weight plant tissue to soil mixtures in pots. Individually each pot was placed in a desiccator and wet to either 100 or 60% of field capacity (FC) moisture levels for Experiment I with an additional treatment of 20% of FC for Experiment II. In Experiment I Coker soybean tissue was incubated single 7d incubation period during which time no air flowed across the soil surface; the incubation was followed immediately with a 4d dry-down period during which moisture- and NH_3-free air was passed across the soil surface at a constant flow rate. Ammonia liberated from the soybean:soil mixture was collected during the dry-down period. In Experiment II Tracy soybean tissue was used for four repeated wet-dry cycles, each consisting of a 7d incubation period followed by a 7d dry- collection period, and then rewetting to the original moisture treatment before the next cycle. Liberated NH_3 was trapped in 0.1M HCl in boats. All experiments were conducted in a constant temperature room.

RESULTS and INTERPRETATION: We found gaseous NH_3 losses from soybean:soil mixtures were highly associated with evaporative loss of water from the soil. More NH_3 is volatilized at FC than at 60 or 20% FC. We also found more NH_3 volatilized at 30°C than at 20°C or 10°C, and more at the 150g soybean rate than at the 75g soybean rate. This N loss is significant with four cycle repetition giving over 5% N loss for a 30°C, FC, 150g soybean tissue run. Since an estimated 3000 Gg of N are returned to cropland soils in soybean residues annually, then even a 5% loss is appreciable, and losses are likely much higher. Since our soybean tissue was obtained from tops after harvest, a greener manure would be expected to produce an even greater N loss. Analysis of the oven-dry soil following the incubation dry-down period showed significantly higher levels of NH_4-N at higher moisture level. This

observation is consistent with data in Experiment II showing apparent increased rates of mineralization at higher moisture level. We found that volatilized NH_3 from soybean-residue amended soil showed fractionation between ^{14}N and ^{15}N isotopes with the leading fraction lower in atom% ^{15}N than the trailing fraction. The fractionation parallels trends observed in steam distillation of NH_3, diffusion of NH_3, and NH_3 volatilization from senescing wheat.

FUTURE PLANS: Studies have been conducted on twelve soil-soybean residue treatments to assess the importance of depth of soybean placement on the volatilization of NH_3 during crop residue decomposition. The data from these studies is currently being analyzed.

ESTABLISHING SOIL CARBON POOL SIZES AND FLUXES FROM SOIL ORGANIC MATTER TURNOVER

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CRIS: 5402-11000-004-00D

PROBLEM: Greenhouse gas concentrations in the atmosphere - especially of CO_2 - are steadily rising. Since the beginning of the industrial revolution in the 19th century, atmospheric CO_2 concentration has risen from about 280 to 353 ppm and is projected to reach 600 ppm during the 21st century. Soil organic matter (SOM) is known to act both as a source and a sink in global CO_2 cycles. Its role in the biological productivity of managed and unmanaged systems is equally well recognized. Central to any rigorous examination of the above roles are questions relating to what is there and what is happening to it? That is, what are the pools and the fluxes involved? In order to better understand how to address this problem, Dr. Eldor Paul from Michigan State University was invited to spend a 6-mo sabbatical with the Soil-Plant-Nutrient RU. Dr. Paul is internationally known for his work with C isotopes and his visit was extremely beneficial to our program. We will continue to collaborate with him on this project.

APPROACH: The first research requirement in determining pool sizes and fluxes is a well-characterized site. Since man's activities play such a profound role, these sites should be representative of the major climatic areas and the management that has occurred. Baseline information is then important for a good evaluation. Information is available in the literature about changes in the size of the organic matter pool of Great Plains soils. However, techniques must be evaluated to assess fluxes. Tracers allow one to identify specific fractions and to measure their turnover rates. Use of tracers, therefore, is vital in identifying pool sizes and determining at what speed materials flow in and out of them. A most useful tracer for soil-C in otherwise unlabeled Great Plains soils is that provided by the discrimination that occurs in the C_3 (Calvin) cycle and C_4 (Hatch-Slack) cycle of plants grown on the same site for ^{13}C and ^{12}C (both stable isotopes of C). The ratio of ^{13}C to ^{12}C is expressed in terms of a "delta" value that indicates less ^{13}C as delta becomes more negative. Availability of accurate, automated mass spectrometers for stable isotope analyses now makes it possible to process numerous samples containing microgram quantities of C.

RESULTS and INTERPRETATION: Great Plains soil samples were obtained from virgin grassland sites extending from Saskatchewan, Canada down through the Great Plains of the USA to central Texas. Vegetation found on these sites ranged from mostly C_3 plants (cool-season grasses) in Saskatchewan to mostly C_4 plants (warm-season grasses) in Texas with corresponding delta ^{13}C values ranging from -26 to -15. Because of the long-term records at Akron, CO in the central Great Plains, more intensive studies are being conducted at that site to assess C fluxes that have resulted to the present time from conversion of this mostly warm-season virgin grass

prairie site, in the early 1900's, to winter wheat (a cool season grass). This same approach is planned for other Great Plains sites as well.

FUTURE PLANS: Considerable time has been needed to develop analytical procedures and to settle upon standard soils and standard delta ^{13}C values. Some procedure development and testing is continuing. Collection of soil samples from the Great Plains transect is completed, although further site specific sampling and data collection is planned. Publication of manuscripts will also be moved forward.

EFFECT OF IRON AND IRON CHELATORS ON WHEAT RESIDUE DECOMPOSITION

William J. Hunter
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: Fungi are important agents in residue decay. It may be possible to reduce the loss of beneficial residue cover from the field by slowing the activity of decay fungi by the use of antagonistic agents.

APPROACH: In this study the effect of iron additions and chelators on residue decomposition was investigated. The synthetic chelator ethylenediamine di-o-hydroxyphenylacetic acid (EDDHA) binds Fe^{+3} with a stability constant of $\log_{10}$ of $K=33.9$ and had been shown to inhibit germination of *Fusarium* chlamydospores. EDDHA resembles the biological iron chelators produced by *Pseudomonas* in that both have a high affinity for iron and both can inhibit growth by binding the available iron. Iron is often a limiting nutrient and biological competition for iron often limits the growth of microorganisms. If chelation studies show that iron is a limiting component in residue loss then it might be practical to use iron chelating biological control agents to slow the loss of residue.

APPROACH: Field dried wheat residue, *Triticum aestivum* cv. Oslo was incubated aerobically in 100 ml serum bottles containing 1 g of residue, 50 g of sand and 10.8 mls of residue buffer. Each serum bottle was inoculated with 1.2 ml of freshly collected soil extract. Treatments were control (no iron or chelator), 10 μM of FeCl, 10 μM iron ethylenediaminetetraacetic acid (FeEDTA) and 10 μM EDDHA. Incubations were in the dark at 30°C. Residue loss was followed by CO_2 production and dry weight change over time. Data was taken at 0, 1, 2, 3, 4, 5, 6, 7, 8, and 16 weeks.

FINDINGS: During the first week of incubation there was little decomposition of the wheat straw. This initial lag in the rate of residue decomposition was observed with all treatment. After the first week of incubation the residue begin to decompose rapidly and the highest rate of residue loss occurred between weeks 1 and 2. Residue loss continued throughout the remaining portion of the study though the rate of loss slowed with increasing incubation time. By the end of the incubation similar amounts; 36 ± 2, 36 ± 3, 36 ± 4 and 35 ± 2% of the residue weight was lost in the control, FeCl, FeEDTA, and EDDHA groups, respectively. Moreover, very similar decomposition patterns were observed with all treatment groups.

INTERPRETATION: These results show that none of the treatments, neither the addition of iron in the form of FeCl or FeEDTA, nor the removal of iron by complexing it with the EDDHA chelator, impacted the rate of wheat straw residue decomposition.

FUTURE PLANS: The 10μM EDDHA concentration used in the initial phase of this study did not slow the rate of wheat straw decomposition. A study using 10 and 100X this level of EDDHA is planned.

BIOREMEDIATION OF HIGH NITRATE WELL WATER USING INNOCUOUS VEGETABLE OIL

William J. Hunter and Ronald F. Follett
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D, 0500-00026-016-04T

PROBLEM: Nitrate contamination of surface and subsurface waters is a major local, national and international problem. Nitrate in drinking water is a health threat to both humans and farm animals. In humans it has been linked to methemoglobinemia in infants and cancer in adults. The maximum permissible level for drinking water in the USA has been set at 10 ppm nitrate-N. Many areas exceed this limit. Only about 30% of the water from the South Platte River Aquifer in northern Colorado meets this standard. In some areas water from this aquifer exceeds the maximum permissible level four fold. Agriculture contributes to this problem as nitrate leaches from irrigated farmlands and feedlots above the aquifer.

The objective of this project is to evaluate a method for eliminating nitrate from pumped groundwater. The method uses innocuous vegetable oil as a carbon source to stimulate denitrification. It may be used *in situ* by the injection of oil around the base of a well or used in above ground sand and gravel filters. Because oil is insoluble in water it forms a plume of oil droplets when injected. These droplets do not flow with the water but instead become trapped by the soil and form, in essence, a filter through which the groundwater flows. Microorganisms, capable of removing nitrate by denitrification, are naturally present in the vadose zone and water table. The absence of an appropriate carbon source normally limits the activity of these denitrifying microorganisms. The vegetable oil provides the needed carbon source, allowing the denitrifying organisms to actively utilize the nitrates presence in the groundwater as a term electron acceptor for anaerobic respiration.

The procedure proposed here differs from earlier studies in two important aspects. First, the carbon source, a vegetable oil, does not dissolve in the water and thus will does not move with the water. This allows the oil to remain in place and act as a filter through which the water moves. Second, the water is being treated only at the point from which it is removed from the aquifer. This is a much simpler and less expensive approach than attempting to treat the water as it enters an aquifer as other approaches have suggested.

APPROACH: Batch experiments were conducted in anaerobic static bioreactors. Sand was used as the solid support, dilute buffer solution as the aqueous phase, and soil extract as the source of denitrifiers. The major treatment variables were the amount of nitrate and oil. The major determinations were the rate of denitrification and rate of oil decomposition.

Experiments using flow columns are also underway. Both sand as well as aquifer matrix material have been used a solid support with buffer or unaltered aquifer water as the aqueous

phase. Materials for the column studies were collected from the Central Plains Experimental Range in northeastern Colorado and from the San Luis Valley in south central Colorado.

FINDINGS: From experiments using static bioreactors the following information has been gained: 1) Both corn and soybean oil are suitable carbon sources for denitrification. 2) Only a short period of time, 24 to 48 hours, is required for the denitrifying population to begin denitrification with vegetable oil as a sole carbon source. 3) Denitrification proceeds over a wide range of oil concentrations--from 0.08 to 133 μl of oil/gram of sand have been tested and found to support denitrification. 4) High levels of nitrate, up to 180 ppm nitrate have been tested, do not inhibit the process. 5) As long as oil is present in excess amounts all detectable nitrate is removed by the process.

Column studies show that oil, injected as an emulsion into 2.5 by 30 cm columns containing aquifer matrix, also removed nitrate (16 ppm-N) from flowing (30 ml/day) unmodified aquifer water containing 6 to 7 ppm oxygen. Small amounts of oil, as little as 10 μl, will initiate denitrification, though larger amounts are needed to sustain the effect. When injected with sufficient oil the columns are effective for extended periods. The first column was set up in April of 1993 and is still operating at the present time. This column was packed with sand and received 1 ml of vegetable oil as an emulsion and a 3 ml soil extract inoculum. It has been pumped at a rate of 26 ml per day (approximately one column void volume per day) with buffer containing 11.5 ppm nitrate-N. Average nitrate levels in the column effluent have remained below 0.2 ppm and nitrite levels below 0.1 ppm since April.

Columns have been sectioned into four equal parts and oil content and denitrifier population determined for the sections. Results show that both oil and denitrifier populations are largely confined to the first column section. This suggests that there is considerable excess column capacity and that the size of the columns can be reduced or that the flow rates used can be increased.

INTERPRETATION: These preliminary studies demonstrate that a simple filter composed of sand, gravel and small amounts of vegetable oil can be used to remove nitrate from pumped ground water for extended periods of time. It is not necessary to introduce specialized or adapted microorganisms; organisms native to the water table are present that are capable of carrying out denitrification using vegetable oil. The presence of oxygen in the water does not prevent the filter from working.

FUTURE PLANS: Future work will be directed at confirming the preliminary data obtained in CY 93 and at determining the capacity and efficiency of the system.

EFFECT OF HERBICIDES AND ANTAGONISTIC MICROORGANISMS ON CROP RESIDUE DECOMPOSITION

William J. Hunter
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: Winter wheat-sorghum-fallow, wheat-corn-fallow, and winter wheat fallow crop rotations are prevalent in the Central Great Plains of the United States. In recent years, the use of minimum-tillage and no-till; where corn, sorghum or other crops are drilled into the existing wheat stubble; have become increasingly popular in these rotations. This procedure depends upon the use of herbicides to control weeds and upon the careful management of crop residues throughout the crop rotation. However, little information exists on the effect different herbicides have on the rate of residue decomposition. Recent reports by the Soil Conservation Service suggest that some herbicides, primarily paraquat, atrazine and glyphosate may accelerate the breakdown of crop residue. This issue is important in that a residue cover on the field protects the soil from erosion while increasing weed control, water infiltration, water conservation and crop yields. Also, the Conservation Compliance program in the 1990 Farm Bill requires a 30 percent residue cover in many individual farm conservation plans.

As with herbicides, little information is available on the effects antagonistic microorganisms may have on the decomposition rate of crop residue. In this part of the study, a commercial preparation called "Mycostop", based on an isolate of *Streptomyces griseoviridis*, was examined. "Mycostop" is a biofungicide that inhibits the growth of seed-borne and soil-borne fungi and thereby protects plants from pathogenic fungi. Cellulolytic fungi are the major agents responsible for the decay of crop residue.

APPROACH: The effect "Mycostop" and paraquat have on the rate of wheat residue decomposition was examined in laboratory studies. The basic procedure involves incubations of air dried wheat residue in small bioreactors under conditions of controlled temperature and moisture. At predetermined intervals, the biological activity of the microorganisms is assayed using carbon dioxide production and residue weight loss as an indicators of the rate of decomposition.

FINDINGS: Neither paraquat (at 1X or 10X field application rates), its sticker nor "Mycostop" were found to effect the rate of residue decomposition when measured by CO_2 production. Though, a slight, perhaps significant (0.05), increase in the rate of residue decomposition was observed with paraquat at 10X field application rates when dry weights were used to measure residue decomposition. Dry weight measurements are more accurate and more sensitive than CO_2 measurements.

INTERPRETATION: The results suggest that paraquat at normal application rates should not increase the rate of residue decomposition.

FUTURE PLANS: Materials from this study are being analyzed in a collaborative study with the ARS Remote Sensing Research Unit in Beltsville, MD and NASA in Greenbelt, MD. These studies are investigating the effect of decomposition upon the fluorescence of crop residues. Data obtained from these studies may help in the development of remote sensing procedures for quantifying the crop residue cover present on a field. An abstract is being submitted and a manuscript is in preparation.

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Publications

Anthony, W.H., Hutchinson, G.L., and Doxtader, K.G. 1993. Oxygen concentration controls on soil emission of gaseous N oxides. Agron. Abstr. 85:240.

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1993. NLEAP, Southern Database, Version 1.2. Soil Sci. Soc. Amer. Madison, WI

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1993. NLEAP, West1 Database, Version 1.2. Soil Sci. Soc. Amer. Madison, WI.

Bronson, K.F. and Mosier, A.R. 1993. Nitrous oxide emissions and methane consumption in wheat and corn-cropped systems in Northeastern Colorado. pp. 133-144. IN L.A. Harper, A.R. Mosier, J.M. Duxbury and D.E. Rolston (eds.). Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55. Am. Soc. Agron. Madison, WI.

Bronson, K.F. and Mosier, A.R. 1993. Effect of nitrogen fertilizer and nitrification inhibitors on methane and nitrous oxide fluxes in irrigated corn. IN Biogeochemistry of Global Change. pp. 278-289. R.S. Oremland (ed.). Chapman and Hall, New York.

Clapp, C.E., Allmaras, R.R., Higgins, D.R., Porter, L.K., Hayes, M.H.B., Molina, J.A.E., Lamb, J.A. and Dowdy, R.H.. 1993. Carbon sequestration in corn-soybean agroecosystems. Abstr. Conf. Greenhouse Gases and Carbon Sequestration. p. 60. Ohio State Univ., Columbus, OH.

Delgado, J.A., Mosier, A.R., Valentine, D.W., Ojima, D.S., Parton, W.J. and Schimel, D.S. 1993. Methane and nitrous oxide flux in nonfertilized, dryland wheat and grassland in northeastern Colorado. p. 124. IN International Symposium Soil Processes and Management Systems Greenhouse Gas Emissions and Carbon Sequestration Abstracts. Columbus, Ohio, April 5-9, 1993.

Delgado, J.A., Mosier, A.R., Valentine, D.W., Parton, W.J. and Schimel, D.S. 1993. Long term ^{15}N studies in a soil catena of the shortgrass steppe. Agron. Abstr. 85:245.

Duxbury, J.M., Harper, L.A. and Mosier, A.R. 1993. Contributions of agroecosystems to global climate change. pp. 1-18. IN L.A. Harper, A.R. Mosier, J.M. Duxbury and D.E. Rolston (eds.). Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55. Am. Soc. Agron. Madison, WI.

Duxbury, J.M. and Mosier, A.R. 1993. Status and issues concerning agricultural emissions of greenhouse gases. pp. 229-258. IN H.M. Kaiser and T.E. Drennen (eds.). Agricultural Dimensions of Global Climate Change. St. Lucie Press. Delray Beach, FL.

Follett, R.F., Porter, L.K. and Halvorson, A.D. 1993. Microbial biomass dynamics using ^{15}N labeled fertilizer in a 4 year crop rotation study. Agron. Abstr. 85:247.

Follett, R.F. 1993. USDA-ARS Nationwide Annual Report for Global Change Research: Biogeochemical Dynamics -- 1992. Compiled and distributed by R.F. Follett. 64 p.

Follett, R.F. 1993. Agricultural activities and nonpoint pollution: Nitrogen. IN Y.P. Hsieh (ed). Proceedings of the Critical Issues in Water Quality: A Workshop (April 19-21, 1993; Tallahassee FL). Florida A&M Univ. (Invited Keynote Paper).

Follett, R.F., L.K. Porter and Halvorson, A.D.. 1993. Microbial biomass dynamics using ^{15}N-labeled fertilizer in a 4 year crop rotation study. Agron. Abstr. p. 247.

Follett, R.F. 1993. Global Climate Change, U.S. Agriculture, and Carbon Dioxide. J. Prod. Agric. 6:181-190.

Follett, R.F. 1993. Agricultural activities and water quality: Nitrogen. p.43. Vol. 12, Part 1. 74th Annual Meeting of the Pacific Division, AAAS. June 20-24, 1993. Missoula, MT. (Abstract).

Freney, J.R., Chen, D.L., Mosier, A.R., Rochester, I.J., Constable, G.A. and Chalk, P.M. 1993. Use of nitrification inhibitors to increase fertilizer nitrogen recovery and lint yield in irrigated corn. Fert. Res. 34:37-44.

Groffman, P.M., Zak, D.R., Christensen, S., Mosier, A.R. and Tiedje, J.M. 1993. Early spring nitrogen dynamics in a temperate forest landscape. Ecology 74:1579-1585.

Harper, L.A., Mosier, A.R., Duxbury, J.M. and Rolston, D.E. (eds.). 1993. Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55. Am. Soc. Agron., Madison, WI. 206 p.

Holland, E., Melillo, J., Mosier, A.R., Ojima, D.S. and Robertson, P. 1993. Building a U.S. Trace Gas Network. Agron. Abstr. 85:252.

Hunter, W. J. 1993. Ethylene production by root nodules and effect of ethylene on nodulation in *Glycine max*. Appl. Environ. Microbiol. 59:1947-1950.

Hunter, W. J. and L. D. Kuykendall. 1993. Biosynthesis of IAA by *Pseudomonas aeruginosa*. Pseudomonas Newsletter. 18(2):2.

Hunter, W. J. and L. D. Kuykendall. 1993. The biosynthesis of IAA by *Pseudomonas aeruginosa*. Abstracts of the Annual Meeting of the American Society for Microbiology. p. 277.

Hunter, W. J. and L. D. Kuykendall. 1993. The symbiotic effectiveness of 5-methyltryptophan resistant mutants of *Bradyrhizobium japonicum*. p. 727 In R. Palacios, J. Mora and W. E. Newton (eds.) New horizons in N_2 fixation. Kluwer Academic, Dordrecht. 788 pp.

Hunter, W. J. 1993. Carbon dioxide production by decomposing wheat residue inoculated with *Streptomyces griseoviridis*. Supplement to Plant Physiol. 102(1):173.

Hutchinson, G.L. and Livingston, G.P. 1993. Use of chamber systems to measure trace gas fluxes, pp. 63-78. IN: L.A. Harper, A.R. Mosier, J.M. Duxbury, and D.E. Rolston (eds.) Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55, Madison, WI.

Hutchinson, G.L., Livingston, G.P. and Brams, E.A. 1993. Nitric and nitrous oxide evolution from managed subtropical grassland. pp. 290-316. IN: R.S. Oremland (ed.) Biogeochemistry of Global Change: Radiatively Active Trace Gases. Chapman & Hall, Inc., NY.

Hutchinson, G.L., Guenzi, W.D. and Livingston, G.P. 1993. Soil water controls on aerobic soil emission of gaseous N oxides. Soil Biol. Biochem. 25:1-9.

Hutchinson, G.L. and Davidson, E.A. 1993. Processes for production and consumption of gaseous nitrogen oxides in soil, pp. 79-93. IN: L.A. Harper, A.R. Mosier, J.M. Duxbury, and D.E. Rolston (eds.) Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55, Madison, WI.

Keerthisinghe, D.G., Freney, J.R. and Mosier, A.R. 1993. Effect of wax-coated calcium carbide and nitrapyrin on nitrogen loss and methane emission from dry-seeded flooded rice. Biol. Fert. Soils 16:71-75.

Kuykendall, L. D. and W. J. Hunter. 1993. Characterization of new *Bradyrhizobium japonicum* tryptophan auxotrophs produced by marker exchange mutagenesis. p. 554 In R. Palacios, J. Mora and W. E. Newton (eds.) New horizons in N_2 fixation. Kluwer Academic, Dordrecht. 788 pp.

Lindau, C.W., Bollich, P.K. DeLaune, R.D., Mosier, A.R. and Bronson, K.F. 1993. Methane mitigation in flooded rice fields. Biol. Fert. Soils 15:174-178.

Lober, R.W. and Reeder, J.D. 1993. Modified waterlogged incubation method for assessing nitrogen mineralization in soils and soil aggregates. Soil Sci. Soc. Am. J. 57:400-403.

Lober, R.W. and Reeder, J.D. 1993. Modified waterlogged incubation method for assessing nitrogen mineralization - soils/ soil aggregates. Agron. Abstr. 83:283.

Mosier, A.R. 1993. State of knowledge about nitrous oxide emissions from agricultural soils. Mitteil. Deutschen Bodenkund. Gesellschaft 69:201-208.

Mosier, A.R. and Schimel, D.S. 1993. Nitrification and Denitrification. pp. 181-208. In R. Knowles and T.H. Blackburn (eds.). Nitrogen Isotope Techniques. Academic Press, Inc. New York.

Mosier, A.R. and Delgado, J.A. 1993. Methane and nitrous oxide fluxes in managed grasslands in Western Puerto Rico. Agron. Abstr. 85:255.

Mosier, A.R. and Bouwman, A.F. 1993. Working group report: nitrous oxide emissions from agricultural soils. pp. 343-346. IN A.R. van Amstel (ed.).Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control Proceedings. National Institute of Public Health and Environmental Protection. Bilthoven, The Netherlands.

Mosier, A.R. 1993. Nitrous oxide emissions from agricultural soils. pp. 273-285. In A.R. van Amstel (ed.). Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control Proceedings. National Institute of Public Health and Environmental Protection. Bilthoven, The Netherlands.

Mosier, A.R., Valentine, D.W., Schimel, D.S., Parton, W.J. and Ojima, D.S. 1993. Methane consumption in the Colorado short grass steppe. Mitteil. Deutschen Bodenkund. Gesellschaft 69:219-226.

Mosier, A.R., Delgado, J.A., Follett, R.F. and Cochran, V.L. 1993. Soil-atmosphere exchange of CH_4 and N_2O in western Puerto Rican grasslands. EOS Supplement. p. 136.

Mosier, A.R., Delgado, J.A., Follett, R.F. and Cochran, V.L. 1993. Soil-atmosphere exchange of CH_4 and N_2O in western Puerto Rican grasslands. Abstract for the Annual meeting of the American Geophysical Union. (San Francisco, Ca. Dec. 1993.). Eos 74:136.

Mosier, A.R., Klemedtsson, L.K., Sommerfeld, R.A. and Musselman, R.C. 1993. Methane and nitrous oxide flux in a Wyoming subalpine meadow. Global Biogeochem. Cycles 7:771-784.

Ojima, D.S. Valentine, D.W., Mosier, A.R., Parton, W.J. and Schimel, D.S. 1993. Chemosphere 26:675-685.

Paul, E.A., Collins, H., Paustian, K., Leavitt, S.W., Elliott, E., Follett, R.F., Cole, C.V. and Kimball, B. 1993. Establishing the pool sizes and fluxes in CO_2 emissions from soil organic matter turnover. IN ABSTRACTS of an International Symposium on Soil Processes and Management Systems -- Greenhouse Gas Emissions and Carbon Sequestration. Columbus, OH (April 5-9, 1993).

Paul, E. A., Follett, R.F., Black, A., Halvorson, A.D., Lyon, D. and Harris, D. 1993. Carbon dynamics of Great Plains soils. Agron. Abstr. 85:257.

Porter, L.K., Follett, R.F. and Halvorson, A.D. 1993. Plant ^{15}N uptake in a 4-year dryland rotation under no-till. Agron. Abstr. 85:282.

Porter, L.K., Follett, R.F. and Halvorson, A.D.. 1993. Plant ^{15}N uptake in a 4-year dryland rotation under no-till. Agron. Abstr. p. 282.

Scharf, P.C., Alley, M.M. and Lei, Y.Z. 1993. Spring nitrogen on winter wheat: I. Farmer-field validation of tissue test-based rate recommendations. Agron. J. 85:1181-1186.

Scharf, P.C. and Alley, M.M. 1993. Chlorophyll meter readings as predictors of optimum topdress N rate for winter wheat. Agron. Abstr. p. 285.

Scharf, P.C. and Alley, M.M. 1993. Spring nitrogen on winter wheat: II. A flexible multicomponent rate recommendation system. Agron. J. 85: 1186-1192.

Smith, C.J., Freney, J.R. and Mosier, A.R. 1993. Effect of acetylene provided by wax-coated calcium carbide on transformations of urea nitrogen applied to an irrigated wheat crop. Biol. Fert. Soils 16:86-92.

Sommerfeld, R.A., Mosier, A.R. and Musselman, R.C. 1993. CO_2, CH_4 and N_2O flux through a Wyoming snowpack and implications for global budgets. Nature. 361:140-142.

Valentine, D.W., Parton, W.J. Ojima, D.S. Mosier, A.R. and Schimel, D.S. 1993. A process-level model of methane uptake in temperate grasslands. EOS Supplement. p. 152.

Patents

Hunter, W.J., Follett, R.F. and Cary, J.W. Bioremediation of water containing high levels of nitrate using vegetable oil in bioreactors. Patent application in preparation.

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MISSION STATEMENT

Utilize distinctive site environmental and disease-free characteristics and specifically developed team expertise to: develop new knowledge and adapt biotechnologies to modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemiology in sugarbeet and other plant species pertinent to sugarbeet cultivation; discover new information and techniques to identify and produce genotypes exhibiting superior disease and stress tolerance and agronomic qualities; and provide new knowledge that improves production efficiency and biochemical processing characteristics of sugarbeet.

TECHNOLOGY TRANSFER - 1993

Sugarbeet Research Unit

Sue Martin

Presented a talk on the potential use of Crucifer secondary metabolites to manage plant parasitic nematodes to scientists and growers in Saskatoon, Sask.; 1993.

Presented two papers at the biennial meeting of the American Society of Sugar Beet Technologists to sugarbeet growers and sugar company personnel as well as other scientists; March 1993.

Presented research results at the annual meeting of the Western Sugar Co.-Grower Joint Research Committee, January 1993.

Presented a summary of research being conducted to eight visiting Egyptian scientists (July 1993) and two French scientists (Feb. 1993).

Lee Panella

Discussed research plans and current research with two French scientists (Feb. 1993), a scientist from the Netherlands (June 1993), and eight Egyptian scientists (July 1993).

Earl Ruppel

Presented a research paper at the biennial meeting of the American Society of Sugar Beet Technologists to sugarbeet growers and sugar company personnel as well as other scientists; March 1993.

Discussed research with two French scientists (Feb. 1993), a scientist from the Netherlands (June 1993), eight Egyptian scientists (July 1993), and another Egyptian scientist (August 15-18).

Participated in several meetings of the Rhizomania Task Force to update sugarbeet growers and sugar company personnel on the incidence of the disease in Colorado and methods for its containment.

Several meetings with sugarbeet growers and sugar company agriculturists in the field to diagnose disease problems and means for disease suppression or control.

A SUGARBEET DISEASE NEW TO COLORADO DISCOVERED NEAR WIGGENS

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: Rhizomania, or "root madness", is a devastating disease of sugarbeet first reported from Italy in 1952. In 1965, Japanese researchers identified the causal agent as the beet necrotic yellow vein virus (BYNVV), which is transmitted by a primitive, soilborne fungus, *Polymyxa betae*. Yield losses average 20-50%, although 100% losses have been reported. The disease first was recognized in the U.S. in California in 1983, appeared in the Texas Panhandle in 1986, and in Idaho and Nebraska in 1992. I found the disease in a sugarbeet field near Wiggens, CO, in August 1993. Because the fungal vector with BYNVV persists for at least 25 years in the soil, once discovered, an infested field essentially is useless for future sugarbeet crops.

APPROACH: Because there are no fungicides to control the vector, and the development of genetically resistant sugarbeet cultivars still is in the initial stages, the main approach to disease suppression is through the containment of the viruliferous vector within known infested fields. Thus, it is important to identify the degree of spread of the disease from the initially identified infested field. In a cooperative effort with Agriculturists of the Western Sugar Company, the Extension Plant Pathologist from Colorado State University, pathologists from the Universities of Wyoming and Nebraska, a survey was planned and carried out to collect beet and soil samples from a 5-mile radius around the initial infestation. Samples then were bioassayed via ELISA at the USDA-ARS lab in Salinas, CA, and at the University of Nebraska Panhandle Experiment Station in Scottsbluff, NB. Subsequently, in consultation with sugar company personnel, a plan for disease containment was developed.

FINDINGS: BNYVV and its vector were found in eight of 13 fields within the 5-mile zone. Root and sugar yields, however, were not drastically affected. Two other viruses, one closely related to BNYVV, also were found in root samples, but their role in the disease syndrome is unknown at this time.

INTERPRETATION: The minimal effect of rhizomania on root and sugar yields indicates that the initial infection probably occurred late in the growing season. Sugarbeet is planted when soil temperatures are too cool for germination and infection by the fungal vector, and, like most plant diseases, more severe losses occur when infection occurs early in the crops' growth stage.

FUTURE PLANS: Continued cooperation with sugar company personnel and University pathologists will be maintained to assure compliance of growers with containment measures. Additional root and soil samples will be collected for immunological testing via ELISA.

FIELD EVALUATIONS OF SUGARBEET FOR LEAF SPOT RESISTANCE

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: Sugarbeet leaf spot, caused by *Cercospora beticola*, is a disease of worldwide importance. Suppression of the pathogen with fungicides is expensive and not environmentally sound. Moreover, in some growing areas, the fungus has become resistant to the most effective chemicals. Genetic resistance is the most economical and logical means of reducing losses from this disease, and our laboratory has been instrumental in the development of *Cercospora*-resistant germplasms for over 60 years. Additionally, our expertise in the development of suitable field epiphytotics of leaf spot is utilized by commercial and research sugarbeet breeders for testing hybrids produced with our resistant materials.

APPROACH: The Fort Collins area is relatively free of naturally occurring Cercospora leaf spot; however, by creating the necessary humid conditions via repeated overhead sprinkler irrigations, we are able to establish adequate field epiphytotics. Each year, four or five sugar or beet seed companies submit more than 200 lines for evaluation in replicated tests in our nursery. *C. beticola* inoculum is prepared from infected leaves gathered the previous year. Inoculations are performed twice at a 1-week interval, followed by repeated overhead irrigation to create a high relative humidity and, later, to help disperse fungal spores via splashing water.

FINDINGS: Only cool weather inhibits or slows the development of leaf spot in our nurseries. Without exception, our internal leaf spot-resistant control entry has less disease than 95% or more of the commercial lines. Using our resistant germplasms in formulating their hybrids, sugarbeet breeders have made steady improvements in leaf spot resistance in their commercial varieties.

INTERPRETATION: Our annual field leaf spot nursery provides an objective means for sugarbeet breeders to have their lines and varieties evaluated for resistance to *C. beticola*. The nursery also enables us to test lines in our germplasm enhancement efforts to increase the level of resistance to this serious pathogen.

FUTURE PLANS: We will continue to provide this service.

RHIZOCTONIA RESISTANCE EVALUATIONS

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: Rhizoctonia root rot of mature sugarbeets, induced by *Rhizoctonia solani*, occurs in most production areas, causing serious yield losses. Partially rotted roots that end up in the sugar factory create additional problems in sugar extraction. No chemicals are registered for suppressing this disease, and cultural control measures have only a modicum of success in reducing losses. We have found and developed the only source of genetic resistance to this pathogen, which company breeders incorporate into their cultivars. However, most companies do not have the expertise or facilities for mass production of inoculum for use in establishing a disease nursery. Moreover, in many company areas, other root diseases preclude accurate assessment of resistance to *R. solani*. Our experimental fields are relatively free of other disease problems.

APPROACH: We produce inoculum by growing the fungus on moist barley grain. After suitable growth, we air-dry the colonized grain, then grind it in a Wiley mill. Inoculum is applied to the crowns of 2-month-old beets in the field, and overhead sprinkler irrigation is used intermittently throughout the day for 4 days to wet the inoculum and stimulate fungal growth. Evaluations for degree of rot are performed at harvest. Besides our Unit's tests of lines being developed in our germplasm enhancement efforts, approximately 175 lines from six to seven companies also are evaluated annually in separate tests.

FINDINGS: Our objective evaluations of breeders' lines have led to the development of adequate levels of resistance in several commercial cultivars.

INTERPRETATION: In production areas where Rhizoctonia root rot is endemic, use of the resistant cultivars has significantly reduced losses caused by this pathogen.

FUTURE PLANS: Rhizoctonia root rot incidence is increasing in several production areas. We will continue to improve resistance in our germplasms and evaluate breeders' lines in our disease nursery.

CHEMICAL DIFFERENTIATION OF RESISTANCE TO RHIZOCTONIA IN SUGARBEET

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: Currently, the only effective and reproducible means of differentiating resistance to *Rhizoctonia solani* in sugarbeet is via costly field inoculations and evaluations. A laboratory technique to screen germplasms before field tests would accelerate our germplasm enhancement efforts and reduce the cost of field operations.

APPROACH: Dr. John Halloin (USDA, ARS, Sugarbeet, Bean & Cereal Research, East Lansing, MI) has developed a chemical color-reaction test that reportedly differentiates Rhizoctonia resistant and susceptible sugarbeet germplasms in the laboratory (*personal communication*). Plugs of tissue were removed from test roots and the holes filled with $HgCl_2$. After 1 hr at room temperature, the roots were incubated at 15 C for 3-4 days. Roots then were bisected through the holes. Successive applications of 10% $NaNO_2$, 20% urea, and 10% acetic acid were atomized onto the exposed tissue. After 2 min, 2N NaOH was applied to the tissue, and color changes were recorded. Test roots included a highly resistant germplasm, a highly susceptible line, and a moderately resistant commercial variety.

FINDINGS: Color changes were noted; however, we were unable to detect differences among the test lines.

INTERPRETATION: It is possible that only roots of certain growth stages differentially react to the chemicals, or some other pre-test conditions are necessary to predispose the roots to the treatments.

FUTURE PLANS: We will consult further with Dr. Halloin and repeat the chemical test with other germplasms. However, the lengthy duration of the test and the need to incubate the roots in a controlled-temperature unit preclude the use of the test for large-scale, replicated evaluations of many germplasms. Also, the intensity of the color reaction, apparently, must be assessed rather subjectively, and intermediate degrees of resistance might be overlooked.

EFFECT OF LEAF- AND ROOT-EXTRACT MEDIA FROM SUGARBEET CULTIVARS HAVING VARIED LEVELS OF RESISTANCE ON GROWTH OF *RHIZOCTONIA* IN VITRO

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: All sugarbeet germplasms developed in our germplasm enhancement program for resistance to *Rhizoctonia solani* are evaluated in an inoculated field nursery. A laboratory procedure to pre-screen germplasms for degree of resistance would reduce costly field testing.

APPROACH: We prepared aqueous extracts of leaf and root tissue of two highly resistant germplasms, two moderately resistant commercial varieties, a highly susceptible germplasm, and a highly susceptible commercial variety. The extracts were made by boiling leaf and root tissue in distilled water and straining the juice through cheesecloth. With the extracts, we prepared broth and agar media, which we "seeded" with 4-mm-diameter agar/hyphal plugs of *R. solani*. At 4 and 8 days, fungal growth in broth was washed, dried, and weighed; colony diameter was measured on the solid agar medium.

FINDINGS: Although there were highly significant differences among cultivars in growth of the pathogen in or on all media types, growth was not correlated with degree of resistance in any medium. Indeed, in some tests, growth was greater in or on media prepared from the highly resistant lines than in or on media from the highly susceptible lines.

INTERPRETATION: Either there are no preexisting chemical determinants of resistance in sugarbeet leaf or root tissue, or boiling the tissues in water inactivated or denatured any compounds that may be present. It also is possible that such substances, if there are any, may not be soluble in water.

FUTURE PLANS: We will repeat the experiment using cold water for extraction from finely triturated sugarbeet tissue.

GERMPLASM DEVELOPMENTS FOR RESISTANCE TO SUGARBEET DISEASES

L. Panella, E. G. Ruppel, and R. J. Hecker (retired)
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: *Rhizoctonia solani* and *Cercospora beticola* are two fungi that may produce a severe reduction of yield in many sugarbeet production areas. Cultural control measures are not adequate by themselves, and often no chemicals are registered for control of these diseases, or chemical control is expensive or environmentally unsafe. Increased levels of genetic resistance are needed to minimize growers' losses from these diseases.

APPROACH: Genetic information developed previously in our research was used to execute additional cycles of pathogen inoculation, plant selection, and recombination among germplasms that we have in our cyclic improvement program. Germplasms in various stages of improvement were evaluated for resistance in inoculated field tests. Results of these tests were the basis of decisions about specific germplasm, i.e., retain, shelve, discard, recombine, release, register, etc. Germplasms likely to be useful for variety improvement were identified and released for use by other sugarbeet breeders.

FINDINGS: Lines developed under the breeding program of Dr. R. J. Hecker are still being evaluated in the field. Thirteen lines were field-tested this summer for resistance to *R. solani*, *C. beticola*, and the curly top virus (Table 1). Seed was increased from three lines, FC709(4X), FC710(4X), and FC712(4X), that are being converted to tetraploidy (4X) with colchicine treatment. They are lines that previously were released from the Fort Collins program as diploids (2X), with high resistance to Rhizoctonia root rot and good combining ability. A few more lines developed in Dr. Hecker's program were increased in isolation plots this summer.

FUTURE PLANS: Lines showing outstanding performance in 1993 field trials will be released in 1994. One of the tetraploids, along with a few other lines increased this summer, will be tested in the summer of 1994 and the best of these lines released.

Table 1. The performance in three disease nurseries of previously released Fort Collins (FC) germplasms and thirteen lines being considered for release.

		Disease Indices		
Source	Designation	Curly Top	Leaf Spot	Rhizoctonia
921002HO	FC604	---	4.5	---
921002HO1	FC604CMS	---	3.8	---
911026HO	FC715	7.0	3.7	1.3
911026HO1	FC715CMS	6.3	3.5	1.0
911028	FC716	6.3	3.7	1.2
911031	FC717	6.7	4.0	1.0
911032	FC718	6.3	4.2	1.1
911037	FC719	5.7	4.2	1.2
931006HO		5.7	5.0	1.4
931006HO1		5.0	4.2	1.3
931007		5.3	4.2	1.3
921007		6.3	4.0	1.2
921008		5.7	4.3	1.2
921012HO		5.3	4.5	1.1
921012HO1		5.3	4.2	1.2
931010		6.7	3.5	1.2
921019		7.0	4.0	0.9
921021		6.3	3.5	1.0
921025		7.3	4.7	1.1
921022		6.3	3.7	1.2
921024		6.7	3.7	1.0
Susceptible Check[1]		5.3	6.3	3.0
Resistant Check[2]		4.7	4.5	1.2
Highly Resistant Check[3]				1.3
LSD		NS	1.1	0.4

[1]Susceptible Check: Curly top = US33, Leaf spot = LSS Synthetic, Rhizoctonia = 831044.

[2]Resistant Check: Curly top = US41, Leaf spot = 821051H2, Rhizoctonia = FC703.

[3]Highly Resistant Check: Rhizoctonia = FC705-1.

BASE POPULATIONS TO DEVELOP MULTIPLE DISEASE RESISTANCE IN SUGARBEET

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CRIS: 5402-21220-002-00D

PROBLEM: In a hybrid crop like sugarbeets, it is preferable that all of the parents contain some level of resistance to diseases prevalent in the area in which the hybrid is to be grown. Multiple disease resistance is a difficult goal in a crop improvement program, especially when working with an outcrossing species. In alternating generations of selection, some of the progress made in resistance to one disease is lost while selecting for resistance to other diseases.

APPROACH: One way of solving the problem of selecting for multiple disease resistance is the use of progeny testing. By testing the progeny of individual mother roots, plants with multiple disease resistance can be identified and used as parents of the next generation. The most efficient use of progeny testing is when the genotype of both parents is known, and the easiest way to do this is through self-pollination. In sugarbeet, there is a dominant, self-fertility allele that permits self-pollination. Used in conjunction with genetic male sterility, to insure cross pollination, a system of full-sib progeny testing can be utilized. Material from the USDA-ARS breeding program at Salinas, CA, will be crossed with some of the Fort Collins lines most resistant to *R. solani* and *C. beticola*. The Salinas material has the self-fertility allele, is segregating for genetic male sterility, and also contains a broad spectrum of resistance to diseases of importance in California as well as other sugarbeet production areas (including rhizomania, powdery mildew, virus yellows, curly top virus, and cyst nematode).

Crosses will be made reciprocally (with some plants from each line as females and some as males). The genetic male sterile plants in the Salinas lines will be used as females, and red (R_) and green (rr) hypocotyl color will be used as markers when the Fort Collins material is used as a female (♂ = R_ and ♀ = rr; only progeny with a red hypocotyl will be used). We also are examining the possibility of using isozyme markers or RFLP markers when the plants with the correct hypocotyl color are not available.

FINDINGS: Five lines from the Salinas breeding program were grown in the steckling field along with five lines from the Fort Collins program. Both multigerm pollinators and monogerm, O-type maintainers were used (Table 2).

FUTURE PLANS: The Salinas lines from the steckling field will be crossed to the Fort Collins disease resistant lines and the F_1 populations intracrossed ('selfed'). The resultant populations, together with the materials from Dr. Hecker's program, eventually will form the basis of two breeding projects, each containing a strong laboratory component. One will focus on understanding the genetics of the *R. solani*-sugarbeet interaction and producing multiple disease

resistance in sugarbeets. The other will focus on understanding the genetics of the *C. beticola*-sugarbeet interaction, and producing strong and stable host plant resistance.

Table 2. The parents to be used in reciprocal crosses to establish breeding base populations.

Line	Origin	Comments
FC604	Fort Collins	Cercospora resistant O-type
FC607	Fort Collins	Cercospora resistant O-type
FC708	Fort Collins	Rhizoctonia resistant O-type
921024	Fort Collins	Rhizoctonia resistant Multigerm
FC902	Fort Collins	Multigerm with some Cercospora resistance
93A001	Salinas	2915, Multigerm segregating for self-fertility and male sterility
93A002	Salinas	R278, Multigerm, self-fertile segregating for genetic male sterility
93A003	Salinas	2890, segregating for O-type, self-fertility and genetic male sterility
93A004	Salinas	N244, Multigerm segregating for self-fertility and male sterility
93A005	Salinas	2859, O-type segregating for self-fertility and genetic male sterility

THE USE OF METHANOL TO INCREASE SUCROSE YIELD OF SUGARBEET

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CRIS: 5402-21220-002-00D

PROBLEM: Recently, researchers reported increased biomass production in agronomic and horticultural plants with foliar applications of methanol. Additionally, an increased water-use efficiency was reported in some crops when methanol was sprayed during times of water stress. An increase in the aboveground biomass of sugarbeet may lead to increased production of sucrose or an increased rate of physiological development in the beet root. This would allow for increased yields of sugar and, possibly, a lengthening of the time during which processing factories could operate due to earlier maturity (and harvest) of the beets. Another benefit would be a decrease in the amount of irrigation water needed to produce the beet crop.

APPROACH: A preliminary yield trial was conducted in the border rows of a nursery plot. Four treatments were: 1) a water-sprayed control (sprayed on 6/16, 7/12, 7/22); 2) three methanol applications starting at the 4- to 6-leaf stage (sprayed on 6/16, 7/12, 7/22); 3) two methanol applications starting at the 4- to 6-leaf stage and ending at full canopy cover (sprayed 6/16, 7/12); and 4) one application after full canopy cover (sprayed on 7/22). Formulation was that given by Nonomura & Benson (1992), with 50% methanol. There were three replications with glycine added to the formulation and three without glycine, arranged in a nested, split-plot design. Final yield data were gathered on the number of roots harvested, total weight of roots harvested, and average sucrose per plot (measured by polarimetry). Plots consisted of two 22-foot rows, with a guard row on either side. Each row was harvested separately, and the averaged data used in the analysis. Data were analyzed with the SAS® GLM procedure.

FINDINGS: We examined visible plant damage from 20, 40, and 60% methanol concentrations with and without glycine. There was no visible difference between the sprayed plants with or without glycine in the formulation. The 60% methanol concentration caused a slight leaf burn in the veins and pockets where the sprayed liquid collected on the leaf. The plants quickly outgrew the damage, and it did not seem to affect subsequent growth. The 40% level caused no visible damage and, therefore, 50% was chosen as the methanol concentration to be sprayed. Unreplicated trials with only glycine as the spray caused a noticeable chlorosis in the leaves, and the plants appeared smaller than the unsprayed plants.

An analysis of variance was performed on the data collected at harvest. For all three variables analyzed (percent sucrose, number of beets, weight of beets), there were no significant differences in glycine effect, treatment effect, or glycine X treatment interactions. The trial coefficients of variations (CVs) were all less than 10, with the CV for percent sucrose at 1.05.

INTERPRETATION: It was possible to apply methanol in a concentration of up to 50% to sugarbeets with no visible leaf damage and no significant loss of yield. It is possible that leaf damage seen at the 60% concentration was due to the Triton X-100® surfactant in the formulation rather than the methanol. No significant differences were seen in yield parameters. The lack of efficacy in this trial may have been due to the unusually mild summer experienced in Fort Collins in 1993. Temperatures were below average, and the field was kept well irrigated because it was a breeding nursery. For the full benefit of the methanol treatment, the plants should be heat and water stressed when the methanol is applied.

FUTURE PLANS: Another trial is planned for the summer of 1994. There will be more replications, with a split plot designed to allow the comparison of water-stressed and non-stressed plants.

Nonomura, A.M., and A.A. Benson. 1992. The path of carbon in photosynthesis: Improved crop yields with methanol. Proc. Natl. Acad. Sci. USA 89:9794-9798.

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[1]Dr. J.N. Nishio is in the Department of Botany at the University of Wyoming.

CLONAL PROPAGATION OF SUGARBEET PLANTS IN VITRO

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CRIS: 5402-21220-002-00D

PROBLEM: Sugarbeet is a crop with an allogamous breeding system (outbreeding) maintained through gametic self-incompatibility. Breeding 'lines' based on this system are really populations of closely related plants whose genetic relatedness depends on a number of parameters, including the initial size of the population, the size of each subsequent population (i.e., stringency of selection), the number of generations, any migration into the population, or any percentage of self-pollination (environmentally influenced). For experimental purposes, it is desirable to be able to test genetically identical individuals to separate variation into genetic and environmental components. Clonally-propagated ramets from a single plant would allow this to be done more efficiently.

APPROACH: We are developing the technology to routinely propagate sugarbeets clonally, using explants from 1) aseptically-germinated seedlings and 2) lateral buds of mature, bolting plants. This will provide genetically uniform material for experimental uses. Other laboratories (industrial and research) have this capability, and we need to develop the expertise and experience to make the procedures routine in our hands. Initial experiments were designed to look at culture of both types of explant. As the laboratory renovation was completed and higher priority projects initiated, efforts were focused on the in vitro propagation from greenhouse-grown plants.

FINDINGS: We have had limited success to this point. We have been able to put explants of both aseptically-germinated seedlings and lateral buds of greenhouse-grown plants into culture, multiply them, and recover plants in the greenhouse, but have not been able to do this consistently. We were able to induce the proliferation of shoots on petiole and leaf cuttings from aseptically-grown seedlings. Greenhouse-grown lateral buds have been cultured, but contamination through endogenous bacteria has been a constant problem. We have used different levels of Clorox and the addition of antibiotics to the culture medium to disinfest these explants with little success. Recently, we have been having greater success using vacuum infiltration of the Clorox. Most of the cultures, however, have a very vitreous appearance, which indicates they cannot successfully be removed from culture to the greenhouse.

INTERPRETATION: Our greatest problem with aseptically-germinated seedlings has been in surface-disinfesting the seeds and retaining adequate germination. The vitreous explants are not satisfactory for multiplying the original plant in vitro.

FUTURE PLANS: We will examine various levels of 6-benzylaminopurine (a phytohormone - plant cytokinin) and gelling agents (agar and Phytogel®) to reduce the vitreous appearance of

our cultures. The vacuum infiltration method of disinfestation, which has proven successful with the lateral buds, will be tried with the sugarbeet seeds to see if a smaller concentration of Clorox can be used. This should improve germination of treated seeds.

GENETIC VARIATION AND PATHOGENICITY IN *RHIZOCTONIA SOLANI*

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CRIS: 5402-21220-002-00D

PROBLEM: *Rhizoctonia solani* is a fungus that may induce a severe yield reduction in many sugarbeet production areas. This fungus is divided into anastomosis groups (AGs) based on the ability of the hyphae to fuse and exchange genetic material, or, more recently, into intraspecific groups (ISGs) based on molecular markers, especially the internal transcribed spacers (ITS) flanking the 5.8S ribosomal RNA gene (rDNA). Isolates of *R. solani* from AG-4 cause seedling damping-off in sugarbeet, and isolates from AG-2-2 cause root and crown root in mature beets. Currently, it is only possible to assay the pathogenicity to sugarbeet of an isolate of *R. solani* through a greenhouse bioassay, which may take 12 to 16 weeks. Although there has been recent work done on the phylogenetics of this pathogen, the evolutionary relationships among isolates have not been well correlated with the host specificity of the fungus. Whether the pathogenicity to sugarbeet has evolved once or more than once could substantially influence the types of host-pathogen interactions.

APPROACH: PCR will be used amplify the DNA of *R. solani* coding for the 5.8S ribosomal RNA gene (rDNA) as well as the two flanking ITS regions. This will be done with the ITS1 and ITS4 primers (Lee & Taylor, 1990). Restriction enzymes that recognize four base-pair sites will be used to create restriction fragment length polymorphisms (RFLPs) from the amplified DNA. These RFLP markers will be used to identify ISGs within AG-2-2. Isozyme markers also are being used to further discriminate ISGs. The *R. solani* isolates then will be tested for their virulence in sugarbeet. The phylogenetic information will be correlated with the pathogenicity data to see if all the isolates pathogenic to sugarbeet belong to the same evolutionary group. In any case, the sugarbeet-pathogenic group(s) will be delineated with genetic markers.

FINDINGS: Currently, DNA from 42 isolates of *R. solani* has been amplified and cut with both *Hpa*II and *Hae*III. Some RFLPs were detected with these two enzymes, as well as differences in the size of the originally amplified length of DNA, which varies from approximately 700 to 750 base pairs.

FUTURE PLANS: Twenty to 40 more isolates of *R. solani* AG-2 will be obtained from diverse locations. They will be analyzed in a similar fashion to the original 42. The DNA will be separated on agarose gels, visualized with ethidium bromide, and photographed. We will use the enlarged photographs to estimate the fragment sizes, using markers of known size (from a *Hae*III digest of ΦX174RFI). More enzymes will be used as needed to discriminate among the

various ISGs in AG-2. Greenhouse tests will be used to determine the pathogenicity of the isolates of *R. solani* to sugarbeet. These data will be correlated with the phylogenetic information.

Lee, S.B., and J.W. Taylor. 1990. Isolation of DNA from fungal mycelia and single spores. Pages 282-287, *in* M.A. Innis, D.H. Gelfand, J.J. Sninsky and T.J. White (eds.), PCR Protocols: A Guide to Methods and Applications. Harcourt Brace Jovanovich, San Diego.

MODE OF ACTION OF TRAP CROPS FOR MANAGEMENT OF THE SUGARBEET CYST NEMATODE

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Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: The sugarbeet cyst nematode (SBCN), *Heterodera schachtii*, is an economically significant pest of sugarbeet. At present, SBCN, an obligate parasite, is controlled by rotation (non-host plants grown for several years before returning to sugarbeet), or by soil treatment with a nematicide. Economic factors (few alternative crops with adequate economic returns) dictate short rotations, and because of undesirable environmental consequences of soil treatment with the effective nematicides, chemical control measures for SBCN may be unavailable within a few years. Thus, an alternative to chemical control of SBCN is being sought. In Europe, cultivars of oil radish (*Raphanus sativus* L.) and yellow mustard (*Sinapis alba* L.), normally hosts of SBCN, have been developed as "trap crops" that promote SBCN cyst "hatching," attraction, and initial plant penetration, but do not support normal reproduction. We are seeking to determine the mode of action of these trap crops, with the goal of understanding how the cultivars that function as trap crops differ from others that serve as hosts for SBCN. Such understanding would be of major importance because better trap crops could be developed more quickly; eventually, the transfer of nematode resistance to other crop plants might be possible.

APPROACH: Our working hypothesis is that chemicals present in the resistant trap crops are involved in the interruption of the SBCN life cycle. The most likely detrimental chemicals are the glucosinolates (GSLs) or their breakdown products, "mustard oils." These are special chemicals present in all members of the plant family Cruciferae (Brassicaceae), to which mustard and radish belong. In work begun in 1993, we are determining GSL content of above- and below-ground portions of SBCN-susceptible vs. SBCN-resistant radish and mustard cultivars at five developmental stages of growth.

FINDINGS: [*Biochemistry*.] In previous work, we developed methods to isolate and separate glucosinolates, and identified those that occur in mustard and radish trap crops for SBCN. Glucosinolate profiles changed both qualitatively and quantitatively through germination and early seedling development of trap crop mustard and radish. In 1993, a quantitative study of GSLs in roots and shoots of trap crop radish and mustard cultivars through development was begun. Plants are greenhouse-grown in sand in a replicated design. At each of five growth stages, three plants per cultivar are harvested, divided into aboveground and below-ground portions, washed, quick-frozen in liquid nitrogen, and freeze-dried. Each dried sample is homogenized in a laboratory mill and sub-sampled for glucosinolate analysis by HPLC. Analyses are in progress and results will be reported in CY 1994.

[1]Research Associate, Beet Sugar Development Foundation

[*Genetics*.] We grew several cultivars of radish and mustard trap crops in the greenhouse and growth chamber to gain increased understanding of their growth characteristics, seed set, and potential for genetic manipulation. Also grown for comparison and inclusion in future studies was *Arabidopsis thaliana*, a small crucifer that has many characteristics that may be of advantage to us in the future. This species, a host plant for SBCN, has been the subject of intensive genetics studies. Mutants lacking one major secondary chemical pathway are available, which may facilitate our investigation of various chemical classes as hatching factors or attractants of SBCN juveniles.

FUTURE PLANS: Studies will continue on biochemical characterization of trap crop cultivars through development. We also plan a 1994 field trial from which plants will be sampled through development and analyzed for glucosinolate content. Work will continue to perfect methods for propagating individual trap crop plants (to obtain multiple genetically identical plants). We will develop methods to obtain and test root exudates of host and trap-crop plants for their effects on SBCN cyst hatching and attraction of infective juveniles. *Arabidopsis thaliana* will be used in some of these tests.

SUGARBEET RESEARCH UNIT

Publications

Duffus, J.E. and Ruppel, E.G. 1993. Diseases. Pages 347-427 *in:* The Sugar Beet Crop. D.A. Cooke and R.K. Scott, eds. Chapman and Hall, London. 675 pp.

Martin, S.S. 1993. Crucifer secondary metabolites and the management of plant parasitic nematodes. Eighth Crucifer Genetics Workshop, Saskatoon, Sask.

Martin, S.S., and Gholson, L.E. 1993. Sugarbeet decomposition in factory storage piles: the good, the bad, and the ugly. J. Sugar Beet Res. 30(1&2):107. Abstract.

Martin, S.S., and Gholson, L.E. 1993. Processing quality assessment of deteriorating sugarbeets: a comparison of visual evaluation vs. analytical data. Amer. J. Bot. 80(6):105. Abstract.

Martin, S.S., Lenssen, A.W., and Townsend, C.E. 1993. Genetic influence on flavonoid stress metabolite accumulation. Int. Symp. Natural Phenols in Plant Resistance, Freising-Weihenstephan, Germany. Abstract.

Martin, S.S., and Narum, J.A. 1993. Sugars and impurities in peel and interior of *Beta vulgaris* roots: changes under short-term, high-quality storage. J. Sugar Beet Res. 30(1&2):108. Abstract.

Panella, L., Kami, J., and Gepts, P. 1993. Vignin diversity in wild and cultivated taxa of *Vigna unguiculata* (L.) (Fabaceae). Econ. Bot. 47:371-386.

Ruppel, E.G. 1993. Potential of *Streptomyces griseoviridis* as a biocontrol agent of sugarbeet soilborne fungal pathogens. J. Sugar Beet Res. 30:113. Abstract.

Ruppel, E.G. 1993. Rhizoctonia root rot: Update on an old nemesis. Western Roundup No. 72, pp. 2-3.

TERRESTRIAL ECOSYSTEMS REGIONAL RESEARCH AND ANALYSIS (TERRA) LABORATORY

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MISSION STATEMENT

To incorporate realistic consideration of land and natural resource management into terrestrial ecosystem components of earth system modeling.

TECHNOLOGY TRANSFER - 1993

Terrestrial Ecosystems Regional Research and Analysis (TERRA)

Most of the research of TERRA is technology transfer, thus it difficult to describe other than in a very general way. In FY'93, TERRA had two meetings with its Board of Directors. At these meetings, the TERRA program was presented by all members of the professional staff. Progress in each research area and testbed of the TERRA Science Plan was described. The staff then revised its program in response to comments from the Board. Several of the TERRA staff also attended a National GIS workshop in Breckenridge and since many of TERRA's Science Advisory Board were present, we presented a general briefing and review of the program. Others attending the meeting were also invited to attend our open-house. It was very well attended and the response indicated excellent support for the program. The TERRA Science Plan which is described in the 1993 Annual Report outlines ten different research activities. Nearly all of our effort in these programs is a form of technology transfer, thus this report will parallel that structure (see that report for a more complete discussion of the science plan).

Collaboration Technology: Collaboration technology, as used here, is use of groupware; software programs to brainstorm, prioritize, and build consensus. We us these programs on a LAN of PC's in group discussion and have held several facilitated sessions (FS, SCS, CRHF and other groups) to demo and use the technology. It was also demonstrated at the GIS workshop in Breckenridge.

Effects Determination: A prototype expert system to determine the major effects of ecosystem perturbation on socio/economic response was developed and demonstrated at a meeting in UK.

GIS/Groupware Integration: Recent linking of GIS and Groupware to enable discussion and use of spatial information in coming to consensus on issues has received much attention, thus we have had numerous demonstrations for many different groups and professional societies.

Conceptual Modeling: Meta Design and CASE tools are being used to develop conceptual descriptions of assessments of ecosystem response to perturbation. It was used successfully to aid the FS in developing a modeling complex to assess a forests response to climate change.

Model Development Tools: The Modular Modeling System (MMS) is being developed jointly with the USGS. It is used to develop, link, test, and evaluate hydrologic process models. I has been very well received and several training sessions on its use have been held with ARS and FS scientists. Also several groups in ARS are implementing it; thus there have been numerous discussions and visits from interested scientists. Documents are being prepared for its first release in about one month. A major responsibility or the ARS-TERRA assignment will be the further development and distribution of MMS.

Other components of the Science Plan are in various stages of development, thus there were no tech transfer meetings. However TERRA is developing several pilot programs to test its concepts. These developments led to many meetings with the Colorado River Headwaters Forum (CRHF) and a Consortium being developed to deal with environmental and economic problems on the Rio Grande and Rio Bravo River Basin. Most of these meetings are discussions of the use of the collection of tools TERRA is developing, thus they are essentially technology transfer.

TERRESTRIAL ECOSYSTEMS REGIONAL RESEARCH and ANALYSIS (TERRA)

Donn G. DeCoursey
TERRA Unit

CRIS: 5402-61000-002-00D

PROBLEM: The terrestrial component of global climate models (GCM's) does not provide a realistic simulation of significant processes and of human influences over these processes. Thus, the Terrestrial Ecosystems Regional Research and Analysis Laboratory (TERRA) was established in Fort Collins, CO. to work with scientists in improving the terrestrial component of GCM's. The Laboratory, composed of representatives of the ARS, FS, USGS, with support from the SCS and the Consortium for International Earth Science Information Network (CIESIN), and in cooperation with IBM works under a Memorandum of Understanding between the USDA and the USDI. The mission of TERRA is **To incorporate realistic consideration of land and natural resource management into terrestrial ecosystem components of earth system modeling.** Thus the challenge is to develop a methodology that will enable TERRA to do two things: (1) enhance scientists' ability to improve the terrestrial component of earth system models and (2) incorporate consideration of natural resource management into the development and assessment of earth system models for policy decisions.

APPROACH: TERRA's approach to this challenge involves developing a process and the tools and technologies needed to implement it. The process is a Structured Analysis Methodology (SAM). A TERRA Science Plan documents the SAM process and describes its implementation. The Structured Analysis Methodology: (1) enhances scientists' ability to improve the terrestrial component of earth system models by implementing a method to assemble and run models with a minimum of effort and (2) incorporates natural resource management into the development and assessment of earth system models for policy decisions using several decision support tools. SAM provides a way of aiding Policy/Decision Makers in evaluating the ramifications of a decision. It uses a computer environment and a series of software programs to complete the assessment. The TERRA staff, working with a facilitator and a group of computer program tools, aids decision makers in the assessment. All decisions are made by the decision makers. Seven steps define the SAM methodology; these are:

- define the problem
- define the temporal and spatial domains of the problem
- assess the likely environmental and social impacts of change
- define a conceptual structure of the assessment
- develop a formal model of the assessment
- complete analysis of the assessment
- interpret the results

The Science Plan has three components: (1) identification of target US Global Change Research Program (USGCRP) needs and activities that TERRA's program addresses, (2) TERRA Research Activities developed to support the application of SAM to natural resource and global change issues, and (3) Pilot Projects to test and validate the SAM and supporting tools and technologies. The TERRA Research Activity Areas are:

- Collaboration technology
- Expert system for effects determination
- GIS-Groupware Integration
- Conceptual modeling tools
- Modular modeling tools
- Networked data resources
- Scale transitions between models
- Expert system for model selection and application
- Distributed modeling
- Data and concept visualization

The pilot projects provide a focus for achieving TERRA goals as well as development of the methodology. Development of the pilot projects and research activities are discussed below.

FINDINGS: This year most effort at TERRA has gone into the first five activities on the list. After reviewing software designed to aid brainstorming, discussion, and consensus building, TERRA selected GroupSystems V, by Ventana as the prototype collaboration tool. It consists of a series of programs that run on a PC LAN. TERRA has used the system several times to enhance organization, documentation and dissemination of information. (See the discussion of GIS-Groupware integration). The ability to conduct meetings in a distributed environment is also being investigated.

Any time that a natural system is perturbed, both the ecosystems and their dependent socio-economic structures respond to enhance or mitigate the perturbation. The result can be a repeating sequence of perturbation and response. TERRA, working with Utah State University, has developed a prototype expert system to aid stakeholders in evaluating the primary and secondary effects of ecosystem response. The expert system "winnows" major impacts of perturbation.

Quite frequently cultural history, beliefs, spiritual significance and personal values affect socio-economic response to ecosystem change. These effects are difficult to express and hard to quantify because they are qualitative. TERRA has enhanced the ability to work with these types of socio-economic modifiers by importing GIS data layers into GroupSystems V. Thus participants in group decision making have the ability to express themselves qualitatively through modification of maps and similar geographically distributed data bases. The effectiveness of the GIS-Groupware integration is being investigated.

After the major components of an assessment have been determined, a methodology that will enable the stakeholders to assemble a conceptual description of the assessment is needed. TERRA is using Meta Design and CASE tools to develop the conceptual descriptions. They were used successfully to aid the Forest Service in developing a modeling complex to assess a forest's response to climate change.

In order to use the conceptual model in making assessments, the conceptual model must be converted into a coded model. Two methods are being investigated by TERRA to accomplish this. One method is use of "whatIf?", a commercial software development environment that can be used to develop simulation models and display their results. The other method is use of the Modular Modeling System (MMS), (Leavesley et.al., 1992). MMS is an integrated software system that has been created to support the development, linking, testing, evaluation and running of process based algorithms and to facilitate the integration of user-selected sets of algorithms into an operational model. Even though the system was designed for temporally-sequential hydrologic model development, it is adaptable to many other kinds of models (plant growth, environmental, socio-economic). Other modules are being added to the system at this time. Most effort this year has gone into the development of an X-windows converter to aid in placing the MMS shell around existing C and FORTRAN code. Also MMS is being changed to enable feedback between modules within a time step.

Several pilot projects have been selected to demonstrate feasibility of the TERRA research program. One of the projects, involves cooperation with the Colorado River Headwaters Forum (CRHF), to determine the consequences of selling excess water from the Climax Metals Company mine site near Leadville, Co. The proposal consists of construction of water handling facilities that will expand an existing reservoir and enable water to be directed into any one of three drainage basins depending upon the demand and benefits. TERRA will be working with the CRHF in assessing future water resources and demands of the area. A second pilot project is associated with sustainability of resource use within the Rio Grande/Rio Bravo River Basin. One Intra-Agency pilot project that is well underway is the coordination of the ARS Global Climate Change Research Program, and efforts to make MMS available to ARS scientists. A key effort in this project is the ARS Climate Change Research Workshop and delivery of MMS, Version 1.0, at Norman OK on Feb. 22-25, 1994.

INTERPRETATION: Progress in implementing the Structured Analysis Methodology is good. The GIS-Groupware prototype is receiving allot of attention in the GIS professional community. Delivery of MMS to ARS scientists will enable better linkage of ARS models and make them more available. Completion of the CRHF project will illustrate the SAM technology and provide a focus for further development. The second pilot project, the Upper Rio Grand River Basin, will show application of the SAM to a larger area.

FUTURE PLANS: Plans for this year will focus on delivery of MMS, further demonstrations of the linkage of GroupSystem V with GIS data bases, and the use of EROS-type data bases in the Mississippi River and Rio Grande/Rio Bravo River Basins.

TERRESTRIAL ECOSYSTEMS RESEARCH AND ANALYSIS (TERRA) LABORATORY

Publications

DeCoursey, D. G., Fox, D. G., Watts, R. D., Woodmansee, R. G., Faber, B. G., and Wallace, W. W. 1993. Terrestrial Ecosystems Regional Research and Analysis: An Interagency Laboratory, In Sam S. Y. Wang, ed., *Advances in Hydro-Science and Engineering*, Vol. I, Univ. of Miss., Univ., MS. pp. 61-70.

DeCoursey, D. G. 1993. Managing Water Resources in the West Under Conditions of Climate Uncertainty: A Review, A review of a book entitled *Managing Water Resources in the West Under Conditions of Climate Uncertainty A Proceedings*, National Research Council, National Academy Press. 344 pp. *Bulletin* of the Amer. Meteorological Soc. Vol. 74, No. 4.

Faber, B. G., Fox, D. G., DeCoursey, D. G., Watts, R., Woodmansee, R. G., and Wallace, W. W. 1993. The TERRA Laboratory: An Interagency Decision Support Environment, Proc. Air and Waste Management Assoc., 93-WA-85.01., 86th Ann. Mtn., Denver, Co.

Faber, B. G., Watts, R., Hautaluoma, J. E., Knutson, J., Wallace, W. W., and Wallace, L. 1994. A Groupware-Enabled GIS, Proc. GIS94 Conference, Vancouver, BC.

Ferreira, V. A., DeCoursey, D. G., and Leavesley, G. H. 1993. An Application of the Modular Modeling System - MMS, Proc. 23rd Annual Workshop on Crop Simulation, Sponsored by USDA-ARS Water Conservation Lab. Phoenix, AZ., Biological Systems Simulation Group and A3 and C3 - Divisions of Am. Soc. of Agr., Tempe, AZ., pp. 1-2.

Fisher, Stuart G. and Woodmansee, Robert G. 1994. Ecological recovery. In *Ecological Risk Assessment.* USEPA. (Technical writing group). In Press.

Fox, D. G, 1993. Global Climate Change and Sustainable Development, Jour. Air and Waste Mgt. Vol. 43, pp. 1202-1212

Fox, Douglas G., Faber, Brenda G., DeCoursey, Donn G., Wallace, William W., Watts, Raymond D., and Woodmansee, Robert G. 1992. The Terrestrial Ecosystems Regional Research and Analysis Laboratory: Regional Collaboration to Address Global Change Issues, In: *Memorias Del II Simposioy I Reunion Nacional Agricultura Sostenible: Un enfoque ecologico, socioeconomico y de desarrollo tecnologico.* Comision de Estudios Ambientales C.P. e Instituto Interamericano de Cooperacion para la Agricultura. 1992. Guadalajara, Mexico. pp. 41-46.

Fox, D. G., D. G. DeCoursey, R. Watts, W. W. Wallace and R. G. Woodmansee. 1994. Global Change, Earth System Science and Sustainable Development. (to be published in Proc. US/Mexican Symp. on Practical Aspects of Sustainable Development Santa Fe, NM, To appear as USDA/FS/RM Technical Report).

Fox, Douglas G., DeCoursey, Donn G., Watts, Raymond G., Faber, Brenda G., Wallace, William W., and Woodmansee, Robert G. 1994. Sustaining our Global Environment through Technology and Cooperation. Keynote address at the 10th Taiwanese Air Pollution Technology Conference, National Sun-Yat Sen University, Kaohsiung, Taiwan.

Fox, Douglas G. 1994. Effects of Global Change on Mountains (in preparation as a chapter for IPCC Working Group II Report.)

Grenney, W. J., Wallace, W. W., and Senti, T. 1993. A Decision Support System to Assist Stakeholders Evaluate A Water Resource Project, in Topping, B. H. V. ed., *Knowledge Based Systems for Civil and Structural Engineering*, Civil-Comp Press, Edinburgh, UK, pp. 145-152.

Heauber, R. A. and Woodmansee, R. G. 1994. Implementing the Sustainable Biosphere Initiative. In Goodland, Robert ed., *Practical Means to Approach Global Environmrntal Sustainability*. World Bank Publication. (In Press).

Nikolov, N. T. and Fox, D. G. 1994. A Coupled Carbon-Water-Energy-Vegetation Model to Assess Responses of Temperate Forest Ecosystems to Changes in Climate and Atmospheric CO_2. Part I. Model Concept, Environmental Pollution, Vol. 83, pp. 251-262.

Peine, J.; Fox, D. G. 1994. Wilderness Environmental Monitoring and Assessment. (to appear as a Chapter in a USDA/FS/SouthEastern Station GTR entitled Wilderness Research: State of Knowledge and Research Needs, Asheville, NC.)

Riebsame, W. E. and Woodmansee., R. G. 1993. Mapping Common Ground on Public Rangelands. In *Let the People Judge: Wise Use and the Private Property Rights Movement*. Island Press, New York. (In Press.)

Woodmansee, Robert. G. and Riebsame, William E. 1994. Evaluating the effects of climate changes on grasslands. Proc. (1993) *International Grassland Congress*. Palmerston North , NZ. (In Press)

WATER MANAGEMENT RESEARCH UNIT

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MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical and alternative weed management systems and irrigation system designs. Improvements are directed towards sustainable, environmentally sound and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and expert systems to transfer new technologies to producers, consultants, action agencies, industry and scientists.

TECHNOLOGY TRANSFER - 1993

Water Management Research Unit

Harold Duke - Administrator for COAGMET, a 25 station statewide agricultural meteorological network in Colorado. Collects and processes weather data daily, including calculation of crop water use, places data in a computer bulletin board system, and provides access information to prospective users. Data are uploaded daily to two commercial satellite services which deliver to more than 1300 farmers and agribusinesses in Colorado on a real-time basis.

Gerald Buchleiter, Harold Duke, Dale Heermann - Assist Extension specialists and SCS Area and Field Office staff in presenting farmer-oriented programs on irrigation scheduling, water management, and irrigation system design. Approximately 10 presentations per year. Provide instrument calibration for cooperating agencies to assure accurate weather data for use in irrigation scheduling.

Gerald Buchleiter, Dale Heermann - Worked directly with USDA-SCS TISD in Fort Collins to assist in implementing ARS technology into SCS national program databases, including incorporation of the SWAN model into FOCS (SCS Field Office Computer System).

Dale Heermann, Gerald Buchleiter - Continue working with industry engineers to incorporate ARS developed irrigation management concepts into base station software being developed by ARS under CRADA with Valmont Industries for commercialization.

Scott Howarth - Served as Special Awards Judge at the 1993 Colorado State Science Fair.

Roger Smith - Delivered 40 copies of OPUS to U.S. ag extension agents, 31 copies to overseas scientists, and assisted users in making program operational. KINEROS program is being used by consultants as described in article in *Civil Engineering*

Lori Wiles - Developed a User's Guide for the GWM model, and presented a workshop to train university scientists on use of the model as part of the NC-202 meeting.

APPLICATION OF GIS FOR WATER AND NITROGEN MANAGEMENT TO PROTECT GROUND WATER QUALITY

D.F. Heermann and M. Paulson
Water Management Research Unit

CRIS: 0500-00032-021-02S SCA: 58-5402-3-119

PROBLEM: It is widely recognized that spatial variability exits in crop production systems. Yields are often quite variable due to variability of soils, water, nutrients and competition with weeds. Prescription farming is being used to provide spatially controlled inputs to compensate for the variabilities. The technology for determining and controlling variable applications is in the development stage. The use of GIS technology appears to offer tremendous assistance in being able to process, display and provide output which can be used in the application of prescription farming. The objective of this project is to develop and explore the capabilities of GIS for improved management of sustainable agriculture systems that minimize the potential degradation of both surface and ground water supplies and conserve water supplies.

APPROACH: Real-time management using climatic and remotely sensed data requires large volumes of spatial data to be processed and interpreted. It is hypothesized that historical data of spatially distributed parameters will be of extreme value when managing a prescription farming system. This project will concentrate on studying the various available GIS programs and developing the interface for the user to query the available data and analyze various management options. The management will be focused both for preseason planning and real time management recommendations. Interfacing prescription application of water and chemicals with computer controlled irrigation systems will be explored. Emphasis will be placed on the development of user an interface for GIS that is user friendly for farmers and managers.

FINDINGS: The research has just begun with little effort expended to date. In preparation for the project, ARCINFO has been installed on the HP Unix machine at AERC and a PC version has been obtained. Preliminary analysis has led to the conclusion that a vector based GIS system will provide the capability to store data at much different scales without excessive disk storage required. Macros are available and can be written for use by those with limited computer experience.

INTERPRETATION: Examples of GIS applications for similar problems demonstrates the benefit of providing visual output for users that increase their interest and ability to interpret large volumes of spatial data. The major change is in the scale of typical applications. Most current examples are for county, state and national scale. The needs of this project are for plot, field and farm scale analyses.

FUTURE PLANS: ARDEC will be the first test case for using GIS at the plot, field, and farm level. The intent is to study how ancillary data from individual scientists, remote sensing

collected with GPS equipment, and photo imagery can be entered into the GIS data based. The processing of these various levels of information into useful management output will be explored. The next step of transferring this information into an automatic computer controlled linear move irrigation system will be started. The progress depends on the parallel development of the capability in the computer programs for communicating and controlling the irrigation system.

UNIFORMITY AND EFFICIENCY OF CHEMICAL APPLICATION THROUGH IRRIGATION SYSTEMS

H.R. Duke, W.C. Bausch, G.W. Buchleiter, D.F. Heermann, and R.E. Smith
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: It is imperative for efficient chemical application that irrigation water be applied uniformly and in depths to control leaching; that the chemical be applied uniformly; that applications be timed for optimum effectiveness; and that the irrigator have the knowledge of variability in soils, crops, and application and the tools to allow him to manage water and chemical application under variable soil, crop, and application conditions. Self-propelled irrigation systems can apply water and solutions of agricultural chemicals uniformly to growing crops after conventional equipment can no longer get into the field. This capability minimizes the need for prophylactic applications of chemical at "layby" to avoid problems which might occur later. Using sprinkler-transported chemical application systems rather than "chemigation" equipment eliminates many problems of preventing chemical backflow into the water supply and of necessity to obtain special registration of pesticides for application by chemigation. Sprinkler applied chemical application holds special promise when used with good irrigation water management for minimizing leaching of agricultural chemicals toward the water table.

APPROACH: The linear move sprinkler at CSU's ARDEC has been modified to allow predetermined differential water and nitrogen fertilizer applications. Cooperative projects have been developed with CSU (Westfall, Cardon, Butters, Waskom) and other ARS researchers (Ahuja, Shaffer, Benjamin) to develop field scale research under this linear system to evaluate optimum water/nitrogen management practices. This project will result in development of systems appropriate for applying nitrogen and water as needed for crop uptake, so as to maintain low levels of water and nitrogen in the soil over the winter period when they are subject to leaching by offseason precipitation. Geographic Information Systems are being applied to field scale problems to develop methods of providing information to the grower which will allow him to best manage his water and ag chemical applications. Combining topographic information, soil data, irrigation system uniformity and water and chemical transport models will allow evaluation of the effects of management decisions, including economic aspects, when applied to situations where variability of several parameters exists. Field plots at ARDEC under the linear move system were planted to corn in 1993; with no nitrogen applied and water scheduled to provide approximately 20% excess in an attempt to reduce the ambient nitrogen in the soil. Canopy reflectance in four distinct wavebands was measured throughout the growing season. Leaf area measurements and chlorophyll (SPAD) readings were taken at least twice per week. Plant samples were obtained at V2, V4, V6, V8, V14, R1, R4 and R6 growth stages for dry matter and N concentration analysis.

FINDINGS: During 1993, emphasis was placed on getting the ARDEC irrigation system operational, reducing ambient nitrogen in the soil profile, and developing and testing equipment to apply variable nitrogen and water applications. Average soil NO_3-N and NH_4-N were reduced from a combined total of 428 kg/ha to 186 kg/ha in the upper 120 cm during the 1993 growing season. The linear system was equipped with in-canopy spray heads, fitted with check valves to allow them to be pulsed on and off as a means of controlling time-averaged water application rates. Laboratory and field tests were completed that showed that water application uniformity of 90% and above could be readily achieved with the system using a one minute pulse cycle time when applications depths exceed 9 mm. Typical applications under the system are in the range of 35 mm. Canopy reflectance in the blue, green and red wavebands tracked the N status of each plot under the linear. However, there was more separation in the data for the green and red waveband reflectances. The blue and red wavebands are chlorophyll absorption bands; thus, the greener the leaf the smaller the reflectance. The green waveband provides the greatest reflectance in the visible portion of the electromagnetic spectrum.

INTERPRETATION: The uniformity of sprinkler irrigation systems is of particular importance when the systems are used for chemical application. Further, application of chemicals only when needed using the sprinkler system shows promise to reduce leaching of chemicals when compared with conventional application methods. Because many agricultural chemicals are readily soluble in water, development of management programs that provide water and chemical only when, where, and in the amount needed have considerable promise to reduce the impact of agriculture on both the quantity and quality of the Nation's water supplies. Such systems minimize the opportunity for chemical leaching either by excess irrigation or by natural precipitation as well as conserve water resources. Remote sensing of the nitrogen status by reflectance measurements will allow rapid real-time assessment of plant nitrogen status. If a single waveband or some combination of wavebands is highly correlated with plant N status, then rapid assessment for N fertilizer requirements over large areas is possible in a "spoon-feeding" management scheme. As methodologies for remotely measuring data are developed, they may replace some of the costly calibration required in current models. As newer sensor technology provides the necessary data on a cost effective basis, improved irrigation system controls will be developed to apply chemicals in an environmentally safe way.

FUTURE PLANS: For the 1994 cropping season, measurements will be made of canopy reflectance, soil water and N concentration, tissue N concentration, canopy temperature, leaf area index, and light penetration through the canopy. Remote measurements will be correlated with direct measurements, to rapidly assess large areas and apply nutrients in the most prudent manner. Upon completion of the plant material N analysis, correlations will be made between plant N concentration and canopy reflectance. Correlations with SPAD meter readings taken throughout the growing season will be investigated to determine the correlation with plant N concentrations. Additional studies are planned for 1994 at ARDEC that cover three nitrogen treatments and two irrigation levels under both sprinkler and surface irrigation in conjunction with ARS and CSU personnel. Digital images in the green and red regions will be acquired as well as color 35 mm pictures converted to CD-ROM format.

IRRIGATION SCHEDULING FOR WATER AND CHEMICAL MANAGEMENT

G.W. Buchleiter, H.R. Duke, W.C. Bausch, R.E. Smith and D.F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Concepts of irrigation scheduling by soil water balance from meteorological data have been available for more than two decades. Producers and action agencies such as the Soil Conservation Service (SCS) are realizing that good water management is essential for controlling fertilizer and pesticide leaching. Researchers have developed numerous models for management of irrigation water and nitrogen under irrigated lands. There is a need for consensus on the most appropriate algorithms for inclusion in user-oriented models and for assembling such models, distributing to potential users, and supporting the models once distributed.

APPROACH: Work continues to support the ARS irrigation scheduling program developed by this group. A Colorado weather data base has been started to make necessary data available to those who wish to use the program. A model capable of using additional kinds of data for making recommendations on water and nitrogen management at the field level is necessary. A systems engineering approach is being used to evaluate user requirements that have been identified by ARS, SCS, university personnel and producers. Existing models will be studied to determine the most appropriate algorithms from each to meet these needs. Technical aspects of model formulation will be conducted by the ARS and university scientists. SCS Technical Information Services Division (TISD) in Fort Collins will develop input/output formats and will be responsible for distribution and user support for the models in the SCS organization.

FINDINGS: Requests from producers, action agencies, and scientists for the scheduling program continue to be strong. More than 120 copies of the program have been distributed throughout the world during the past 4 years. Direct support was given to several technically oriented farmers throughout the U.S. who are using the programs. Particularly Buchleiter and Duke have responded to numerous requests from Extension, SCS and consultant groups to participate in farmer-oriented water management workshops throughout the Plains and on the Western Slope of Colorado. Technology transfer was promoted by assisting SCS and Extension personnel in checking instrument calibration, trouble shooting instruments, and answering questions about operating the program. Duke cooperated with personnel in CSU's Dept. of Plant Pathology and Weed Science to coordinate procurement and installation of a multiple use weather station network throughout Colorado. The group has installed 25 weather stations, many of which were purchased by producers and commodity groups. The data from this network are used to provide real-time forecasts of pest infestation and crop water use information for irrigation scheduling. The data are collected daily, via hardline or cellular telephone connections, by the microcomputer in Duke's office, and stored on the Water Management network server at AERC. Water Management developed a bulletin board (BBS) on that server so that growers can access the data. During the 1993 growing season, the data

were accessed more than 1700 times. Water use and weather data are also being uploaded to two satellite delivery systems which provide data with 15 minute delay to more than 1300 farmers and agribusinesses in Colorado. A 1993 survey conducted by CSU Extension showed that the ET information was the second most used information put on the units, after weather forecasts, and farmers reported an average value of the information in excess of $1400 per farm. Buchleiter worked cooperatively with SCS TISD personnel to test and validate SPAW, a core hydrology model that is scheduled to be implemented in SCS field offices in 1994. A simulation study was begun to evaluate SPAW's performance for corn on a sandy soil. Input was solicited from the SCS on the requirements of a Soil Water And Nitrogen (SWAN) model. Refinements to the requirements of this model continue. Several studies were initiated to begin evaluating technologies that are appropriate to be included in this model. A cooperative study with the Great Plains Systems Research Unit was begun to evaluate the Root Zone Water Quality Model (RZWQM) for corn on a sandy soil.

INTERPRETATION: Producers and action agencies are becoming more concerned about the potential for leaching of agricultural chemicals from improper irrigation management. As water quality concerns grow, irrigators will be required to control the movement of agricultural chemicals into the nation's water supply. One of the primary means of controlling chemicals is by control of the water, which is the principal means of chemical transport. As regulations increase, it is important that the technologies used to plan, execute, and evaluate the management practices be consistent. The availability of programs usable by the irrigator will allow more informed day-to-day, water management decisions. Incorporation of crop growth models and chemical transport models will further enhance the producer's ability to control chemical transport. This cooperative program development represents a major commitment by ARS to support other action agencies within the U.S. Department of Agriculture.

FUTURE PLANS: Limited technical support to SCS and Extension personnel and to producers implementing the current scheduling program will continue. Weather data from the Statewide network will continue to be processed for the short term (through 1994), while assisting CSU Extension and Experiment Station to pursue avenues of obtaining permanent support for the network. Upon completing the various requirements of the SWAN project, OPUS and other existing models will be compared to determine which technology/algorithms are appropriate for meeting the defined requirements. Comprehensive soil water data sets such as those collected at the CSU Agricultural Research, Demonstration, and Education Center, will be used as part of this evaluation process. The appropriate algorithms will be integrated in a model and validated. SCS programmers will be responsible for coding and implementing these models in the UNIX environment of their field offices. A similar computer program that is graphically oriented and operating under DOS will be developed for individual producers to use for making water and fertilizer management decisions on a real-time basis. This program could also be implemented as part of an integrated multi-discipline management software package for self-propelled sprinklers. Cooperative work will continue with the SCS to implement the interim core hydrology model that is to be implemented in 1994 within the SCS organization.

MANAGEMENT DECISIONS AIDED BY REMOTELY SENSED INPUTS

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Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Seventy-eight percent of the irrigated corn in the 17 Western states is grown in Colorado, Kansas and Nebraska. This constitutes 50 % of the total irrigated area in these three states. Water, nitrogen, and weed management strategies for irrigated corn can benefit from remotely sensed inputs. Irrigation scheduling models utilize reference ET and crop coefficients to estimate actual crop ET. Crop coefficients used to adjust computed reference ET for a specific crop are based on averages of several years data and reflect 'average' crop development rates. Whenever crop growth rates depart from this average rate, the traditional crop coefficient may be in significant error. Consequently, actual crop ET may be different than estimated which could result in over- as well as under-irrigation. Real-time nitrogen management of a crop has tremendous potential for reducing nitrate contamination of ground water. Various techniques (direct and indirect) have been developed to determine N status in plant tissue. However, these techniques are laborious and time consuming. Leaf reflectance at various wavelengths has been correlated to leaf chlorophyll; unfortunately, applications have not been developed for monitoring N status at the plant canopy level. Excessive herbicide applications to control anticipated weed problems is causing ground and surface water contamination. Rapid detection and classification of weed species after crop emergence would encourage mapping the weed population for spot application with selective herbicides.

APPROACH: Five corn crop coefficient curves [the curve used in SCHED (the USDA ARS irrigation scheduling program), tabulated data by Wright, the linear segment curve by Hinkle et al., the curve by Stegman, and the curve developed using real-time reflectance data] were selected to evaluate their "goodness" to estimate corn ET throughout the growing season. Corn ET was measured using the Bowen ratio energy balance (BREB) method. Reflectance of the crop/soil scene in two specific wavebands (red and near IR) was computed from measurements of reflected and incoming light using intercalibrated radiometers. The reflectance-based crop coefficient was computed from these data. Leaf area and soil moisture were also measured. Corn grown at ARDEC in linear move sprinkler and surge irrigated plots (in cooperation with Cardon and Westfall, CSU Agronomy) was used to obtain reflectance data to further correlate with leaf N concentration and chlorophyll measurements. Each irrigated area was divided into four plots. Residual nitrogen (NO_3-N + NH_4-N) in the upper four feet of the soil profile varied from 190 to 549 kg/ha. Canopy reflectance was obtained in the blue, green, red and near IR. The radiometer platform was attached to a boom which was mounted on a high-clearance tractor. Chlorophyll measurements made with a SPAD meter and plant samples for N concentration analysis were taken throughout the growing season. A monochrome digital camera was customized to utilize narrowband filters centered at 450, 550, 670 and 840 nm wavelengths. The camera was received too late to obtain weed seedling images during spring-time weed scouting.

FINDINGS: Differences in daily accumulated ET between estimated crop ET for the particular crop coefficient and measured BREB ET indicated that the crop coefficient in SCHED performed best for estimating crop ET; the Hinkle et al. curve was second best with the other three curves showing similar performance. However, an analysis of variance on the linear regressions of measured crop ET versus estimated crop ET indicated no significant difference at the 95 % level among the crop coefficient curves to estimate crop ET. Canopy reflectance in the blue, green and red wavebands tracked the differences in nitrogen content associated with each plot. The green and red wavebands were most responsive. The soil component of the crop/soil scene is a problem before complete canopy cover.

INTERPRETATION: Traditional crop coefficients perform adequately for estimating crop ET as long as crop growth abnormalities do not occur. However, when weather anomalies, nutrient deficiencies, insect damage, disease, etc. affect plant growth, remote sensing can detect this change and be used to compensate for it. The present reflectance-based crop coefficient may require additional changes. The blue and red wavebands are sensitive to chlorophyll absorption. Leaf reflectance in these wavebands is small (red greater than blue); the greener the leaf the smaller the reflectance. Of the three visible region wavebands, reflectance is greatest in the green region; again the greener the leaf the smaller the reflectance. Thus, some combination of the green and red wavebands should allow for the remote estimation of plant N status at the canopy level in lieu of a point measurement represented by a plant leaf or discs punched from a plant leaf. This technology lends itself to rapid assessment of the spatial variability of plant N status over large areas for N management decisions in a spoon-feeding scheme.

FUTURE PLANS: The field study of measuring crop ET and other required parameters will be repeated to obtain a second year of data for further evaluation of traditional crop coefficients as well as the reflectance-based crop coefficient. Correlations will be made between plant N concentration and various combinations of the green and red wavebands. Correlations with SPAD meter readings will be investigated. Cooperative studies will continue with Cardon and Westfall (CSU Agronomy) at ARDEC. Reflectance measurements will be taken throughout the season along with chlorophyll meter readings, plant tissue samples, and soil samples for nitrogen analysis. Digital images in the green and red regions of the electromagnetic spectrum as well as 35 mm color photographs will be acquired as a means for minimizing the soil background problems associated with incomplete canopy conditions. These data, repeated on the same treatments applied to the same plots in subsequent years will provide a solid database for assessment of the relative accuracy of the various methods of scheduling nitrogen applications for optimum control of groundwater quality degradation. Images of weed seedlings (broadleaf and grass) in corn will be acquired when field scouting is conducted to count and identify the seedlings at ARDEC (cooperation with Westra, CSU Weed Science) and on a commercial farm close to ARDEC. These images will be acquired with digital and 35 mm format cameras. GPS technology will be used during acquisition of these images to determine their location in the field for mapping the spatial distribution of the weed seedling populations.

IMAGE ANALYSIS OF WEED SEED AND SEEDLINGS

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CRIS: 5402-13000-004-00D

PROBLEM: Traditionally, high rates of herbicides have been used to control weeds in corn. Several of these chemicals have been detected in surface and ground water. To justify the need for herbicides, it may be feasible to detect and classify weed species by remote sensing. One option would be to acquire images after crop emergence. Another option would be to sample weed seedbanks before planting or after harvest. Once weed populations are mapped within a field, herbicides could be applied with spatially variable spray equipment.

APPROACH: To determine spatial resolution, spectral bands and appropriate feature extraction and classification techniques, corn and four weed species will be grown in a greenhouse and imaged. This experiment will determine which factors are necessary for detection and categorization of weed seedlings. All seedlings will be grown in 35 cm by 25 cm (14" by 10") trays, six seed groups per tray for each species. Images will be acquired daily following emergence while seedlings are in the cotyledon to first true leaf stage of development. Lighting will be provided artificially to simulate noonday solar intensity and spectral quality. Two cameras will be used for image acquisition, a still digital camera and a 35 mm camera. The digital camera has four spectral bandpass filters and an IR blocking filter. The center wavelength for the bandpass filters are 450 nm, 550 nm, 650 nm and 870 nm. The 35 mm camera will be used to acquire color pictures that can be transferred to a CD ROM for digital analysis. Soil samples from the weed seedbank will be collected. A seed inspection station will be constructed to separate and present the samples to an imaging station. Features such as size, shape and color will be measured to count and classify weed seeds.

FINDINGS: Equipment for imaging weed seedlings was obtained. Initial findings are expected in the first quarter of CY1994.

INTERPRETATION: No interpretations have been made to date.

FUTURE PLANS: From the initial greenhouse experiment, the appropriate feature extraction and classification techniques will be designed and developed to characterize corn and weed seedlings. Then a second greenhouse experiment will be conducted to validate the initial classification results. This experiment will test the robustness of image analysis algorithms for a mixture of weed species and corn seedlings. The imaging system will then be field tested. Image analysis software will be developed to extract size, shape and color features of weed seed. Classification techniques will be developed to characterize weed species from sand and other debris. Finally, classification results will be compared with those of trained weed seed analysts.

APPLICATION RATES, INFILTRATION, RUNOFF AND EROSION IN IRRIGATION

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CRIS: 5402-13000-004-00D

PROBLEM: Conventional design methods regarding the relationship between application rate and potential runoff under sprinklers usually make simple and erroneous assumptions for infiltration relations. As a result, there is often conflicting beliefs as to appropriate action to reduce runoff: that is, should the irrigator apply smaller amounts more frequently (which will result in a wetter soil surface) or large amounts less frequently to allow the surface to dry between irrigations? Design methods should also account for the effects of spatially varying soil properties, redistribution between wetting events, and the effect of runoff occurrence on total distributional efficiency for a given topography. High application rates under various systems often cause erosion and soil movement both within the field and into tailwater. The use of low pressure nozzles and LEPA systems to reduce energy costs generally means a smaller application pattern and a higher application rate, often causing the potential for runoff, especially on significant slopes. Even under more conventional types of sprinklers, runoff can be a problem, particularly in areas of large slope and heavier soils. Irrigators are expressing an interest in independent control of small sections of the sprinkler as a means of minimizing the effects of soil and topographic variability on runoff or leaching.

APPROACH: Research has treated problems concerning infiltration estimation and furrow flow simulation, including spatially varying soil properties. Data from field experiments are being used to characterize the random spatial variations in soil hydraulic characteristics. Solution of Richards' equation is employed to ask the question: Are there effective mean soil characteristics that can be deduced from soil samples, and if so how can these be found? A second study is focused on the development of an analytic model to estimate redistribution of soil water between wetting events for most soil types. Current analytic infiltration methods do not cover the elongation of the wetting profile between wetting events. Effect of initial wetting profile development at low input rates is a case commonly encountered in rainfall hydrology and under center pivot systems with significant overspray in advance of the arrival of the major sprinkling area. When these complications have been incorporated into an analytic model, it will be possible to form a robust irrigation infiltration model to simulate most any irrigation scenario with any variety of wetting pattern, and to simulate the resulting location and extent of runoff, if any. Such a model will allow simulation of the effects of surface excess under LEPA systems.

FINDINGS: Studies of field-scale infiltration and soil water movement have continued. In general it is not possible to measure an effective hydraulic conductivity relation for heterogeneous soil area, (although such an equivalent relation exists) which can be used in a

single solution of the soil water flow equation. It was also demonstrated that the mean values of saturated water content and residual water content hold their validity for dynamic conditions under heterogeneities. The recently developed simple model for redistribution of water between rain pulses or irrigation pulses was extended to more general conditions, including prewetting without runoff, and other interrupted conditions where inputs occur without causing runoff. This extension is directly applicable to irrigation conditions. Development and testing of a general, fixed grid, furrow flow simulation model was continued, for use in a spatial model for irrigation simulation using GIS techniques. A joint study was begun with Paulo Luz of Portugal with some encouraging initial results, to evaluate use of modern infiltration theory in analysis of the soil response to particular patterns of intensity under various sprinkler patterns and rates of movement. Cooperative research with Silsoe College, England, under an EC research grant, has developed an improved dynamic erosion model for rilled or furrowed topographies to be used in field verification studies throughout Europe. A release version has been completed and writing of the documentation is underway. Erosion and infiltration modeling improvements have also been incorporated into a new version of KINEROS, an ARS hydrology model developed in cooperation with David Goodrich and Carl Unkrich at Tucson, which is scheduled for release in the near future.

INTERPRETATION: As the trend to use low pressure sprinkler systems continues, irrigators must be made aware of the tradeoffs involved. Controlling potential runoff is essential not only for reducing energy usage but also for minimizing water quality degradation from erosion and leaching of chemicals. The ability to simulate realistically how the soil responds to various input patterns and the effect of spatial variations is crucial to studying the potential for improved irrigation efficiency and management of chemicals which are applied either with or separately from irrigation. Scientists must be able to account for both spatial variation of soil properties, and the complexities of the interaction between input rates and infiltration rates. As more complex models are made available to producers or SCS personnel for use in field situations, research may be needed to either (1) establish practical methods for obtaining the required parameters from existing readily available databases e.g. SCS soils Data Base or (2) define and have some agreement within the technical community on which parameters are most needed and how they should be measured. Data must be either readily available or relatively quick and easy to obtain, if we want producers to voluntarily use these technologies.

FUTURE PLANS: A camera based data collection method is being designed for use in studying the variability of furrow advance ahead of the linear move irrigation at ARDEC. Significant variation has already been observed. This data will give unique insight into the variability of intake rates both in time and space. Further integration of the unit's distribution simulation models and the analytic infiltration models are planned, for use in better evaluating the crop-sensitive results of various irrigation rates. Reports of research now being completed are underway, intended for technical journal articles. Technical help is needed to make further progress in integration of our knowledge into a GIS-based model for whole-field analysis of irrigation and chemigation efficiency.

ARS LIAISON TO SCS

D.F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: The Technology Information Systems Division (TISD) of the SCS is responsible to develop, support, and maintain a technology information system (TECHIS). The system consists of conservation planning resource inventory, conservation effects, and practice design tools together with supporting data bases needed by SCS National Headquarters, State, area, and field offices to carry out their tasks. ARS has an extensive history of developing new technology which has been used by SCS. The need exists to improve ARS cooperation with our customer (SCS) to appropriately transfer ARS developed technology and establish protocols for establishing high priority research projects within ARS.

APPROACH: The liaison role was established to assist in the development of protocols for cooperation or partnership which will enhance the development and delivery of technology by ARS and SCS. My time will be split between my research responsibilities for the Water Management Research Unit and the liaison position. I will meet and interact with the SCS TISD division in Fort Collins. An office cubical is provided in the SCS facilities.

FINDINGS: A memorandum of understanding between the U.S. Department of Agriculture, Agricultural Research Service and the Soil Conservation Service was signed on July 1, 1993. This was only five months later than targeted at the ARS-SCS Partnering Workshop. The memorandum defines the partnering domain from the categorization of needs through implementation, including maintenance and support. As part of the implementation of the memorandum, a 12 person ARS/SCS Partnership Management Team (PMT) was appointed. Jerry Seinwell (SCS) and Dick Amerman (ARS) are the co-chairs of this team. This team has appointed four work groups. Each has been given a charge and asked to report back to the PMT. Work groups have been assigned for 1) Prioritization Process, 2) Computing Environments, 3) Ecosystem Based Natural Resource Management, and 4) Data Bases. An element in the memorandum that is critical to the success of the Partnership is the Certification of the technology. Dick Amerman called a meeting in Beltsville to discuss ARS Software Management. A number of issues were identified but no specific conclusions or recommendations were developed. The concensus was that a team of unspecified size and composition should be organized to provide the interface with the SCS (a primary user) for certifying and controlling the procedure. The procedure needs to be developed with input from modelers and users.

INTERPRETATION: The ARS/SCS Partnership is developing at a slow pace but with deliberate caution to ensure a success. The assigned work groups should provide the next steps to making this an effective partnership. The current activity of Reinventing the Government has

put new constraints on the direction the partnership should go. The reorganization may have an impact on the division of responsibilities for technology development within SCS. This could influence how ARS responds in making the partnership effective. The ARS\SCS partnering is an excellent way for us to interact with one of our major customers. This could greatly impact our ability to continue as a major player in natural resource research in the USDA.

FUTURE PLANS: The next year will be devoted to participation with the PMT and coordinating with the work groups. I will continue learning the needs of SCS in packaging technology for field use, communicating these needs to appropriate ARS scientists, advising SCS of useful technology available in ARS, and developing protocols for cooperation. I intend to become actively involved in evaluating the current technology used by SCS and possibly do evaluation of alternatives as time permits.

IRRIGATION INDUSTRY/ARS COLLABORATIVE EFFORT

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CRIS: 5402-13000-004-00D

PROBLEM: Although there have been some impressive partnerships between the Irrigation Industry and ARS, they had never joined in a concerted, sustained effort to impact irrigation on a broad scale up through the national level. In May 1991, in a workshop setting, an effort was launched by representatives of the Irrigation Industry and ARS to develop a framework within which the two entities could establish a collaborative program to address issues facing irrigation as a whole. Thus, the "Collaborative Effort," led by Dedrick and Heermann, was initiated with the stated purpose:

> For the Irrigation Industry and the Agricultural Research Service to foster and focus an ongoing partnership in support of irrigation that yields optimal societal benefit.

APPROACH: In the May 1991 workshop, over 40 attendees, almost evenly divided between the Irrigation Industry and ARS irrigation and drainage researchers, met to clarify various missions and current programs, identify priority research needs, clarify areas offering significant collaborative opportunities, and decide how best to continue workshop initiatives. At that meeting, a Leadership Group, co-chaired by Dedrick and Heermann, was mandated to lead the Collaborative Effort. Over the last two-and-a-half years, the Leadership Group has guided actions to address the agenda that emerged from the workshop, including semiannual meetings to adjust overall Collaborative Effort plans and to review and support its three Leadership Group subgroups, each of which focuses on one of three main thrusts.

I. Support the Irrigation Association (IA) as key representative of the Irrigation Industry to identify priority research needs and communicate them to the research community,
II. Increase collaborative research carried out by Irrigation Industry and ARS scientists and engineers, and
III. Propose and support a study by the Water and Science Technology Board (WSTB) of the National Academy of Sciences/National Research Council focusing on the future of irrigation in the United States.

FINDINGS: Key results of the Collaborative Effort over the last two-and-a-half years include <u>Identification of Priority Research Needs</u>. IA Division Leaders identified an initial list of five major "Research Opportunity" areas of thirty-two items. IA and ARS representatives met to discuss these Research Opportunities for all areas of irrigation, including turf and landscape, in relation to ARS's ongoing program planning process. Attendees included IA representatives President Bill Koonz, incoming president Joe Goecke, and Executive Director Charles (Pepper) Putnam; and ARS Acting Administrator Essex Finney, Jr., Associate Deputy Administrator Jan van Schilfgaarde, and National Program Leader Dale Bucks. The meeting is viewed as the initiation of a longer-term process for conveying Irrigation Industry research needs to ARS.

Increasing Collaborative Research Carried out by ARS and the Irrigation Industry. Activities in this area have focused on increasing the awareness of Irrigation Industry and ARS scientists and engineers about opportunities for collaborative research. Specific accomplishments include a "Yellow Pages" directory of ARS Irrigation and Drainage researchers, their areas of research, accomplishments, and publications (over 500 copies distributed to date); a Collaborative Effort exhibit at the last three IA Expositions to gain visibility and provide information on collaborative research (support provided by IA and the ARS Offices of Technology Transfer, Interactive Cooperation, and Information); a first-steps "how-to" brochure for entering into Cooperative Research and Development Agreements (CRADAs); and publicity on Collaborative Effort initiatives through news releases and mailings.

Proposing and Supporting the Water Science and Technology Board Irrigation Study. The need to provide an objective, unbiased description of irrigation's present position--its value, problems, and opportunities--to the public was the topic of considerable discussion at the May 1991 workshop. The Leadership Group developed and presented a statement of work for a proposed study on "The Future of Irrigation in the Face of Competing Demands and Water Quality Constraints" to the National Academy of Sciences, Water Science and Technology Board (WSTB), in November 1991. The WSTB agreed in early 1992 to undertake the study. Reports from WSTB studies provide an in-depth analysis of the issues and impacts of various strategies or policies, and they are often used for policy and political decisions. The Study is funded by the Irrigation Association, USDA/ARS, USDI/Bureau of Reclamation, Ford Foundation, and Idaho Power Association, each of whom also provides a liaison to the process.

INTERPRETATION: The enthusiasm of representatives from both the Irrigation Industry and ARS to work toward the Collaborative Effort goals has produced a number of significant accomplishments. The collaborative (Yellow Pages and CRADAs) and ARS-specific research (Research Priorities) have initiated interaction between ARS and the Industry. The WSTB Study will provide a cornerstone for the future of irrigation in the United States. The Collaborative Effort has been successful in building interaction, understanding, and trust between a client group and ARS, and the approach has potential as a model for partnerships with other groups.

FUTURE PLANS: Future efforts will include "seeing through" or maintaining activities already initiated. For the Priority Research Needs, this will require input as appropriate to assist the IA in institutionalizing the process the Research Committee will use. For Increasing Collaborative Research, guidelines for continuation of the Collaborative Effort exhibit annually at the IA Expo will be developed. In addition, a pilot workshop on collaborative research is being considered to introduce industry product engineers to CRADAs and other opportunities for collaboration. The liaison between the Collaborative Effort and the WSTB Study will be maintained, with input provided by the Leadership Group as appropriate. Future meetings of the Leadership Group, as well as adjustments of membership and focus, will depend on progress of the ongoing activities and the requirements of newly identified activities appropriate to the Collaborative Effort's goals.

DESIGN CRITERIA & INTEGRATED MANAGEMENT TECHNOLOGY FOR SURFACE & CENTER PIVOT IRRIGATION SYSTEMS

D.F. Heermann, ADODR and C.W. Fraisse
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CRIS: 5402-13000-004-03S **SCA:** 58-5402-0-003

PROBLEM: Improved management of irrigation systems to apply water and chemicals is needed to increase water use efficiency and prevent degradation of ground water. Integration of management is important to provide for improved operation, because managing any resource by itself can lead to mismanagement of another resource. The implementation of integrated systems requires the testing and developing new concepts for both hardware and software.

APPROACH: A linear move system for experimental water and chemical application requires a control much more sophisticated than one for normal field operations. The different water treatments required are often applied by changing frequency and/or depth of an irrigation. The system installed at the CSU North Ag Campus requires flexibility in both time and space. A solution for the problem of varied application needs along the pipeline is to apply the concept of pulse irrigation. Pulse irrigation is based on a series of pulses, where each pulse is composed of the operating (on) and resting (off) phases. Solenoid valves installed upstream of one or more spray heads enable the flow control. Because each electrical pulse causes the valve to perform one complete cycle, the frequency of operation is limited by the valve's response time. When compared to mechanical valves, solenoid valves are usually lighter and more compact. Unlike manual actuators, solenoids allow remote and automated control with greater reliability.

FINDINGS IN 1993: The design and installation of a 4 span linear move irrigation system for applying differential depths along the lateral has been completed at CSU's Agricultural Research, Development, and Education Center (ARDEC). Differential application can be made on 8 segments along the lateral. The effect of sprinkler pulse duty cycles, smooth and grooved deflector pads, sprinkler height, and timer setting for linear move system was simulated. It was determined that 1 or 1/2 cycles per minute gave adequate uniformities for the simulated start-stop sequences with a linear system. The uniformity decreased with increased percent timer settings. The donut patterns for the smooth deflector pads resulted in higher uniformities than for the grooved deflector pads. This assumed no wind effects. In general the higher the nozzle above the ground, the higher the irrigation uniformity. Field evaluations were conducted and compared quite closely to the simulated results. Neural networks were investigated for their use in building an Expert System for fertilizer recommendations. A large set of learning data is needed to obtain a reliable neural network. Preliminary results indicate that the better approach is to create Crop Advisor systems based on domain experts, then generate a comprehensive learning data set for a NN.

INTERPRETATION: The completed laboratory, field and simulated results provided the data for the design of the linear move system at ARDEC. Field scale applications of pulse irrigation are ready for further tests to provide the capability to differentially apply water under farm sized irrigation systems. This equipment will allow the linear move system to selectively apply the wide range of water and chemical treatments required for research.

FUTURE PLANS: Uniformity of application is an important characteristic of irrigation systems and is even more important when the system is utilized for research. In the case of moving systems, uniformity depends not only on selection of appropriate nozzle sizes, but also on the start-stop characteristics of the system. The preliminary results indicate that not only the start-stop characteristics are important but the variation in speed due to slippage and increased loading on the cart from the drag of the feed hose is important. Additional field data will be collected to determine the magnitude of the change in speed. It is also important to develop a technique to measure the location and ground speed as the system is operating. This can then be used to evaluate different control strategies for compensating for the variation.

INTEGRATED MANAGEMENT SYSTEMS FOR SELF PROPELLED SPRINKLER IRRIGATION SYSTEMS

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CRIS: 5402-13000-004-05T

PROBLEM: Center pivot irrigation systems are used extensively in the Great Plains and Pacific Northwest. There is a continuing need to improve water management, to minimize environmental damage from overirrigation and minimize energy costs. The interactions of the various aspects of crop production (e.g. water and nutrient use, weed and pest control) as well as the complexity of irrigation systems make it difficult to manage effectively. The ability to resolve conflicting crop production practices and to respond quickly to changing operating conditions can enable the producer to improve irrigation practices and reduce production costs.

APPROACH: Producers can improve their management skills by following recommendations from computer models. Models must be easy to use and required data must be relatively easy to obtain and enter. Models must be calibrated, validated and capable of resolving conflicting crop production practices so producers are confident of the results and recommendations. These model programs are integrated with radio telemetry systems which automatically collect data and initiate controls for implementing recommendations. Experiments test sensors for obtaining the necessary data and control algorithms for implementing the recommendations. A Cooperative Research And Development Agreement (CRADA) is in place with Valmont Industries and limited technical assistance is provided to our cooperators to improve the transfer of these newly developed technologies.

FINDINGS IN CY 1993: The initial version of base station software has been marketed by Valmont to approximately 30 locations. Limited technical assistance was given to one farm where the irrigation scheduling program interfaced with the base station software was field tested. The logic for determining and displaying 'false alarms' was modified to meet Valmont's desire to notify the user when programmed operations occur. Program documentation for the restructured base station software was nearly completed. Prototype software for programming pivot operations graphically with a mouse rather than entering the logic and required commands from the keypad was developed and demonstrated to Valmont. A unique small-volume pulsing spray system, composed of injection molded polyethylene parts, was tested in the laboratory to determine design criteria for use as a prescription fertilizer application system to be attached to the sprinkler system. This system is capable of applying UAN fertilizer with a uniformity exceeding 90% when pulsed with a period of about 30 seconds. The system should be able to apply as little as 25 liters/ha of chemical, and will allow uniform application throughout the growing season. Laboratory tests indicated the potential for problems with application amount and uniformity due to temperature fluctuations in the spray system. Work on the linear move machine at ARDEC involved installing and field testing sprinkler equipment and developing

prototype base station software for linear move machines. This machine is equipped to irrigate 24 plots within 6.2 acres which are controlled by ARS, as well as three other plot areas. Multi-function application heads capable of LEPA operation, were installed and positioned about .7 m above the ground to achieve very uniform applications and minimize wind drift for plot work. The heads were manifolded in 8 independently controllable segments. Separate chemical application equipment which produces a pulsing spray, is also being installed on the machine. Programming of the auxiliary controller to differentially apply water and chemicals by pulsing, was begun but was hampered by insufficient memory. A controller with more memory and more robust programming capabilities was obtained. Accurate knowledge of the machine's location in the field is crucial for plot work. Machine slippage data were collected, and indicate that increased length of hose being dragged increases slippage rate. As the machine moves, the CAMS panel counted electric pulses generated by a measuring wheel mounted on the drive cart and recorded sensed status inputs at correction points located at known points along the cart path. Algorithms in the base station software determine distance traveled and the machine's location based on these sensed inputs. Field testing to determine accuracy and reliability of the system was limited.

INTERPRETATION: Several companies have introduced new products offering remote monitoring and control indicating increasing interest in this approach for improving management of irrigation systems. Valmont is aggressively marketing these control systems for production agriculture and municipal land application waste disposal sites. Approximately 35% of Valmont's pivot sales include the programmable CAMS panel which can provide a versatile platform to interface with and deliver newly developed technology directly to the producer. The producers' acceptance depends on the direct cost savings, the ability to incorporate the recommendations into their management style, and the ease in understanding and operating the system. The pulsing spray system adapted for chemical application will eliminate the inherent hazards of conventional chemigation by eliminating the hydraulic connection to the water supply, thus considerably reducing the potential for water contamination by ag chemicals. The system is also readily adaptable to 'spot treatment' under self-propelled sprinklers, a technology which could provide much more effective and efficient use of ag chemicals.

FUTURE PLANS: Numerous machine performance, reliability and model verification experiments are anticipated. A datalogger will record the start-stop sequences of the tower movements to provide data for validating a sprinkler simulation model. Data collection equipment to assess irrigation performance and/or crop status may be installed to provide the input data for models that can improve management. Models such as **OPUS** which deal with infiltration, runoff, nutrient management, water quality and weed management models can be integrated into the system as additional decision making tools. The desired level of model complexity depends on the quality of the data measured and the machine's ability to implement the necessary controls. As part of our CRADA with Valmont, the unique, sequential spray irrigation system will be tested in the laboratory and on the linear move sprinkler to determine hydraulic characteristics appropriate to design for chemical application on self-propelled sprinklers. User feedback will be obtained to refine the graphical programming prototype as an alternative way of programming operations of pivots and linear moves.

IMPROVING WEED CONTROL AND WATER QUALITY WITH TILLAGE AND LESS HERBICIDE

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CRIS: 5400-22000-002-00D

PROBLEM: Alachlor is a commonly used soil-applied herbicide in corn and has been detected in groundwater and surface water. A reduction in the amount of alachlor applied in corn should improve water quality. Early-season weed control is important to minimize weed competition and improve crop yields. Historically, early season weed control research has focused on either soil-applied herbicides or use of tillage implements such as rotary hoes or cultivators. Innovative cultivators (i.e., in-row) designed to control weeds within the corn row may allow for less intensive pre-cultivation weed control (rotary hoeing). Research data which examines reduced herbicide use and mechanical weed control interactions are lacking.

APPROACH: In 1993, the efficacy of reduced alachlor rates to supplement or replace tillage at crop emergence and/or cultivation to control annual weeds was assessed. Variables examined were: seedbanks (low, medium, and high); alachlor rates (zero, 1/3, and 2/3 the labeled recommended rate); tillage at crop emergence (none, one, or two passes of a rotary hoe); and cultivation (standard and in-row cultivator). This study allowed for the assessment of interacting variables on weed management strategies. Weed management efficacy was determined in terms of weed control, crop grain yield, and gross margin (gross income minus weed control costs).

FINDINGS: Weed seedbank had no impact on results. When weed control was assessed after the last cultivation (layby), there were two weed control interactions: cultivator by rotary hoe and cultivator by alachlor rate. For the first interaction, the in-row cultivator plus one or two rotary hoeings controlled the most weeds (Table 1). The standard cultivator plus two rotary hoeings provided only 53% weed control. For the second interaction, weed control was similar to the in-row cultivator alone, the in-row cultivator plus alachlor, and the standard cultivator plus the 2/3 rate of alachlor. Corn yield and gross margin did not differ between any treatment.

INTERPRETATION: When the spectrum of weeds is comprised of alachlor-susceptible species, a reduced rate can adequately control these weeds while reducing costs and minimizing the risk of potential groundwater and surface water contamination. In the absence of alachlor, a rotary hoe is an integral part of a weed management strategy in conjunction with an in-row cultivator. Since rotary hoeing does not provide residual weed control, it must be done after weed seed germination but prior to seedling establishment. The in-row cultivator is a very effective weed management tool. In-row cultivation can provide corn producers with a level of weed control that may allow them to reduce the intensity of pre-cultivation weed control. Gross margin did not differ between treatments, which indicates that the additional weed control provided by the in-row cultivator did not reduce gross margin.

Table 1. Percent weed control as a result of the cultivator by rotary hoeing and cultivator by alachlor rate interactions. The standard cultivator plus no rotary hoeing or standard plus no alachlor served as untreated check. (NOTE: the 1X rate of alachlor is 3 lb/A.

Cultivator x Rotary Hoe		Cultivator x Alachlor Rate	
Cultivator plus Rotary Hoe (RH)	Weed Control (%)	Cultivator plus Rotary Hoe (RH)	Weed Control (%)
STD + No RH	0 a	STD + 0 alachlor	0 a
STD + 1 RH	5 a	STD + 1/3 alachlor	73 b
STD + 2 RH	53 b	STD + 2/3 alachlor	83 bc
IR + No RH	59 c	IR + 0 alachlor	79 bc
IR + 1 RH	86 d	IR + 1/3 alachlor	88 bc
IR + 2 RH	84 d	IR + 2/3 alachlor	91 c

FUTURE PLANS: Additional data analysis will be performed to better understand the interactions of the mechanical and chemical weed control treatments. Data from this two-year study will be analyzed, summarized, and submitted as a manuscript to a refereed scientific journal.

BIOECONOMIC WEED MANAGEMENT DECISION AIDS FOR BARLEY AND DRY BEAN PRODUCTION

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CRIS: 5402-22000-002-00D

PROBLEM: Herbicides are apparently reaching groundwater and surface waters as a result of current crop production practices. Herbicide use can be reduced without compromising net profit through more efficient weed management. Water quality may be protected by helping growers manage weed populations more efficiently.

APPROACH: The use of bioeconomic weed management decision aids can increase the efficiency of weed management and thereby reduce herbicide use. These programs can help decision makers match the selectivity of a control treatment to the composition of the anticipated or actual weed populations. These programs can also do a cost/benefit analysis to ensure that control is used only when the benefits are expected to exceed the costs. A reduction of herbicide use, in comparison to intensive, prophylactic herbicide use has been documented for the use of two existing programs. While herbicide use was reduced, net profit was maintained or increased. The objective of this research is to develop bioeconomic decision aids for weed management decisions in irrigated dry beans and barley.

FINDINGS: As a first step towards developing the dry bean and barley decision support systems, a "general" bioeconomic weed management decision support system, GWM, was developed in cooperation with Dr. R. King at the University of Minnesota. GWM was designed to minimize the programming required to develop models for different crops or to modify inputs and parameters for crop production in another region. A common format for weed management decision models would also make it easier to link models for optimizing weed management within a crop rotation. GWM has two components: a simple bioeconomic simulation model to evaluate weed control options and a database management system for entering field-specific inputs and for parameterizing the simulation model. Versions of GWM were parameterized for irrigated dry bean production in Colorado, Nebraska and Wyoming and for irrigated corn and soybean production in Minnesota with the help of weed scientists in those states. The structure of the simulation model captured essential components of weed management in these crops and was flexible enough to accommodate differences in biology and weed control recommendations between these states and crops. Preliminary model validation trials for the dry bean versions were conducted on research farms and the second year of germination experiments was completed in Colorado. These experiments examined the pattern of weed emergence in dry beans and the effect of weed control treatment on these patterns. A workshop on using GWM was conducted at the summer meeting of the NC202 Regional Research Project (Biological Basis for Development of Bioeconomic Weed Management Models).

INTERPRETATION: Developing weed management decision models is one way to help growers reduce herbicide use, and as a result, protect water quality. A general weed management decision model was structured and programmed as a first step in developing weed management models for dry bean and barley production. The common, general structure will make it easier to modify the models for crop production in different regions. It should also facilitate linking models for different crops together to help growers with weed management decisions within the context of a crop rotation.

FUTURE PLANS: The first general (unparameterized) version of GWM will be released in the spring of 1994 to members of the NC202 Research Project and other interested parties. Data from the field validation trials and emergence experiments will be used to refine parameters of the three dry bean versions. A version for irrigated corn production in Colorado will be parameterized from the structure of WEEDCAM and another version for barley production will be parameterized from the literature and expert opinion.

REFINEMENT OF WEED/CORN MANAGEMENT EXPERT SYSTEM AND DEVELOPMENT OF EDUCATIONAL MATERIALS FOR USERS

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Water Management Research Unit

CRIS: 5402-22000-002-01S **SCA:** 58-5402-1-115

PROBLEM: Little research has been directed toward the economics of weed management. Few bioeconomic weed-crop models have been developed or field tested. Weed-crop models could aid growers and crop consultants to compare the biological and economic efficiency of many alternatives and present easily interpreted recommendations.

APPROACH: A questionnaire was sent to 15 agricultural chemical dealers to ascertain the current prices of corn herbicides. Outreach activities were continued to inform interested customers about WEEDCAM, the CSU/ARS weed/corn bioeconomic model.

FINDINGS: Based on the farm supply firm survey, prices for corn herbicides were updated in the database for WEEDCAM. A Herbicide Environmental Index (HEI) was developed and incorporated into the Post submodel of WEEDCAM. HEI is a relative index based upon quantity of herbicide (active ingredient) applied and the toxicity, persistence, and mobility of the herbicide. HEI is broader than the groundwater orientated screening models. Drafts of manuals for WEEDCAM were initiated. Special presentations of WEEDCAM were made to the Colorado Corn Growers Association and to EPA staff personnel in Washington, DC. EPA personnel are interested in the development of new technology that will reduce pesticide use in American agriculture. WEEDCAM also was presented at the January 1993 Colorado Corn Pest Management Clinic to 120 corn producers and at six extension meetings to educate potential clients about computer modeling developments which can be used to reduce herbicide use in corn. Approximately 50 copies of a video tape describing WEEDCAM and farmers' experiences to the model were distributed in 1993.

INTERPRETATION: Based on four years of data from 50 farm sites, the model suggests that increased gross margins and reduced herbicide loading can be achieved with the weed management model compared to farmer weed management decisions. Transfer of this technology to the Corn Belt States should lead to reduced herbicide use.

FUTURE PLANS: This four-year pilot field research project was completed in 1992. Data are being analyzed and summarized. At least two publications will be submitted to a referred scientific journal. Lybecker and Westra will complete the EPA portion of this agreement by September 30, 1994.

VALIDATION OF WEED MANAGEMENT EXPERT SYSTEMS FOR CORN AND SOYBEANS IN MINNESOTA

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CRIS: 5402-22000-002-02S **SCA:** 58-5402-1-116

PROBLEM: The use of herbicides on corn accounts for roughly 40% of all agricultural herbicide use and 25% of agricultural pesticide use, for a total of 200 million pounds over the nation's 70 million acres of field corn. The bioeconomic weed-corn modeling technology developed by ARS and Colorado State University scientists provides many options for corn producers to use this technology to reduce reliance on herbicides. Since this technology is contributing to the Presidential Initiative on Enhancing Water Quality, ARS and EPA wanted this technology adapted for rainfed agriculture.

APPROACH: WEEDSIM, the corn/soybean model for rainfed conditions, was validated in field trials again in 1993. Field research also was conducted at the Rosemount research center on weed/crop interactions and weed population dynamics to improve the prediction power of WEEDSIM.

FINDINGS: In collaboration with scientists from Colorado, elements of the Minnesota corn and soybean bioeconomic models have been integrated into the General Weed Management Model (GWM) which allows great flexibility regarding the selection of crops, weed species, and weed control alternatives. GWM also has an improved user interface and database structure. A test version of GWM was presented to weed scientists during a day-long training session at the annual meeting of NC-202. Copies of the software and manual were distributed to representatives from participating states for further testing and evaluation. Field trials were conducted for the third year to evaluate corn and soybean weed management strategies based on the bioeconomic model. The soil-applied treatment for corn ranked first by the model had a lower herbicide load, but similar weed control, yield, and net return when compared with the standard treatment. The postemergence treatment ranked first by the model had a lower herbicide load, similar weed control, but lower yield and net margin when compared to the standard treatment. This was due to early competition from weeds and corn injury from cyanazine in the model-based plots.

INTERPRETATION: Data obtained from these experiments will be used to further improve and expand the current models.

FUTURE PLANS: Scientists from Minnesota will continue to collaborate with scientists in Colorado on the development of GWM; work with crop consultants to initiate comparisons of recommendations made by the bioeconomic model with farmers' actual decisions; and work with scientists in Iowa to initiate a series of validation experiments for bioeconomic model

recommendations at several sites in Iowa. An initial version of GWM should be released in 1994. GWM will be used for computer simulation experiments designed to evaluate the economics of: (a) site specific weed management and (b) delayed planting for weed control.

CHARACTERIZING WEED POPULATIONS IN NEBRASKA SOYBEAN FIELDS FOR MORE EFFICIENT MANAGEMENT

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Water Management Research Unit

CRIS: 5402-22000-002-03S **SCA:** 58-5402-3-104

PROBLEM: Pesticides are apparently reaching groundwater and surface water from routine agricultural use. In the corn belt, soybean herbicides have been detected in groundwater and seasonally in surface water. More efficient management of weeds in soybean fields can enhance the quality of groundwater and surface water by reducing the use of herbicides.

APPROACH: Having accurate, field-specific information about weed populations can help growers manage weed populations more efficiently. Applications can be limited to fields, or portions of fields, for which control is economically justified. Treatments could be carefully matched to the composition and spatial distribution of the population in each field, and growers could identify fields in which selective, postemergence control can be substituted for prophylactic, soil-applied treatment. A microcomputer expert system is available to help growers with weed management decisions in soybeans. Simulation experiments will be done to develop a scouting plan for use with this expert system and to determine the value of modifying the model to recommend spatially variable weed control treatments within a field.

FINDINGS: Crop consultants and county extension agents were involved in selecting seven corn and five soybean fields in eastern Nebraska in 1993. Only fields where farmers had applied preemergence herbicides in a 38-cm band over 76 cm spaced rows were chosen. These fields were surveyed intensively to determine the spatial distribution of broadleaf and grass weed seedlings in the interrows and band-treated intrarows. Spatial maps constructed for broadleaf and grass species revealed that individual species, as well as species assemblages, were highly aggregated, and aggregation generally increased as weed density decreased. Based on estimates of weed population means, the percentage of the field area occupied by weeds was calculated using geostatistical analysis. On average, 30% of the sampled area in the 12 fields surveyed was free of broadleaf weeds and 70% free of grass weeds in the interrow area. Application of herbicides increased weed species aggregation, with 71% of the sample area free of broadleaf weeds and 94% free of grass weeds.

INTERPRETATION: The results of these distribution studies indicate that herbicide use could be substantially reduced if weed distribution maps or real-time plant sensing were available to provide information for intermittent herbicide application systems or refinement of economic threshold sampling methodologies.

FUTURE PLANS: The seedling populations in five commercial soybean fields will be sampled in 1994 and the data will be used to model weed spatial distribution, an important input for the

simulation experiments. Agricultural consultants will help design the algorithms for spatially variable treatment decisions and the scouting plans that will be tested in the simulation experiments.

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS

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Water Management Research Unit

CRIS:5402-22000-002-04T

PROBLEM: Weed control with herbicides is economic, convenient and effective. As a result, herbicides have lead the dramatic, recent increase in the amount of pesticide applied, with corn and soybeans receiving approximately 70% of the total amount used. Herbicides are the pesticide most commonly detected in groundwater in the corn belt. Corn and soybean herbicides have also been seasonally detected in surface waters. More efficient weed management can enhance the quality of groundwater and surface water by reducing the use of herbicides.

APPROACH: The efficiency of weed management could be improved if growers had more accurate, field-specific information about the composition and spatial arrangement of weed populations. Applications could be limited to fields, or portions of fields, for which control is economically justified. Treatments could be carefully matched to the composition and spatial distribution of the population in each field, and growers could identify fields in which selective, postemergence treatments can be substituted for prophylactic soil-applied treatments. Herbicide use should be reduced with no loss in net profit. The spatial distribution of weeds in corn and soybean fields will be characterized. This information will be used to develop efficient scouting plans for obtaining weed population information needed when using corn and soybean weed management decision aids. The potential for reduced herbicide use with spatially-variable weed control treatment in corn and soybean fields will also be assessed.

FINDINGS: A soil probe for obtaining consistent cores of 4" depth and 2" diameter and a soil elutriator for separating the weed seeds from the soil in the core were designed and built. An agricultural consultant identified ten commercial corn fields for sampling in the spring of 1993. Of these, two furrow and two center pivot irrigated fields were selected for sampling. Before corn emergence, 1245 soil cores were collected on a square grid pattern in a 20-acre block of each field. After corn emergence, weed seedlings were identified and counted in a 5 foot length of crop row or furrow adjacent to each soil sample site. Sampling time was recorded. Pigweed, nightshade and lambsquarters were the most prevalent seedling species. Foxtail and barnyardgrass were the most prevalent grass species. Usually less than 20 plants of a species per quadrant were observed, but over 500 plants of a species per quadrant were encountered in one field. Seed bank samples are being processed and the time spent processing is being recorded.

INTERPRETATION: Many growers and consultants recognize that having information about the composition and spatial arrangement of a weed population could help them make better weed management decisions. However, they are concerned about the cost of scouting to collect this

information. This research will quantify the cost of scouting and the value of the information obtained and also will help identify efficient scouting plans.

FUTURE PLANS: An additional four commercial corn fields in Colorado will be sampled in 1994. Data from both years will be the basis of simulation experiments to identify optimal scouting strategies and determine the value of spatially variable weed control within a field.

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Publications

Bausch, W.C. 1993. Soil background effects on reflectance-based crop coefficients for corn. Remote Sens. Environ. 46:213-222.

Bausch, W.C. 1993. Evaluation of corn crop coefficients for ET estimation. ASAE Paper No. 93-2525, Am. Soc. Agric. Engrs., St. Joseph, MI.

Buchleiter, G. W. 1993. Appropriate technology for water and nitrogen management. ASAE Paper #932022.

Buchleiter, G.W. 1993. Agricultural water conservation technology transfer. In Proc. of ASCE Conf. "Water Management in the 90's". Seattle, WA, May 1-5. pp. 709-712.

Buchleiter, G.W. and Unruh, R. 1993. Managing center pivots with CAMS and SCHED. In: Proc, 2nd Wkshp. on Crop-Water-Models. 15th ICID Cong."Water Magt. in the Next Century". The Hague, Netherlands, Aug. 30-Sept. 11.

Ells, J.E., McSay, A.E., and Kruse, E.G. 1993. Irrigation scheduling programs for cabbage and zucchini squash. HortTechnology 3(4):448-452,464.

Forcella, F., King, R., Wiles, L., Buhler, D., Swinton, S., Gunsolus, J., and Maxwell, B. 1993. Bioeconomic weed management models. Hort Sci. 28:152.

Jalali-Farahani, H.R., Duke, H.R. and Heermann, D.F. 1993. Physics of surge irrigation II. Quantifying soil physical parameters. Trans. of the ASAE 36(1)37-44.

Jalali-Farahani, H.R., Heermann, D.F., and Duke, H.R. 1993. Physics of surge irrigation II. Relationship between soil physical and hydraulic parameters. Trans. of the ASAE 36(1)45-50.

Kruse, E.G., Champion, D.F., Cuevas, D.L., Yoder, R.E. and Young, D. 1993. Crop water use from shallow, saline water tables. Trans. of the ASAE 36(3):697-707.

Lybecker, D.W., Schweizer, E.E. and Westra, P. 1993. Computer decision aid for managing weeds in irrigated corn. In: Agricultural Research to Protect Water Quality, Soil and Water Conservation Society. 2: 295-297.

Rochester, E.W., Duke, H.R. and Heermann, D.F. 1993. Computer-controlled sensor carriage for simulated center pivot movement. Tech. Note, Trans. of the ASAE 36(3):795-797.

Schweizer, E.E., Westra, P. and Lybecker, D.W. 1993. Alternative tillage systems vs a computer decision aid for controlling weeds within the corn row. In: Agricultural Research to Protect Water Quality, Soil and Water Conservation Society. 2: 298-299.

Schweizer, E.E., Lybecker, D.W., Wiles, L.J. and Westra, P. 1993. Bioeconomic weed management models in crop production. In: International Crop Science I, Chap. 15. 103-107.

Smith, R.E. 1993. Simulation experiments on the role of soil hydraulic characteristics in agro-ecosystems. Modeling Geo-Biosphere Processes. 2:1-14.

Smith, R.E. and B. Diekkrüger. 1992. Field-scale soil water flow in hetrogeneous soils I. Modeling statistical soil variation and large-scale constituent relations. Modeling Geo-biosphere Processes, 1:205-227.

Smith, R.E., Corradini, C., and F. Melone. 1993. Modeling infiltration for multistorm runoff events. Water Resources Research. 29(1):133-144.

VanGessel, M.J., Garrett, K.A., Schweizer, E.E. and Westra P. 1993. Effect of spatial pattern of weeds on corn yields. Weed Sci. Soc. Am. 33:116.

VanGessel, M.J., Schweizer, E.E. and Westra, P. 1993. Weed control in corn with reduced rates of alachlor, cultivation, and/or postemergence herbicides. Proc. West. Soc. Weed Sci. 46:100.

VanGessel, M.J., Wiles, L.J., Schweizer, E.E. and Westra, P. 1993. Weed management in dry beans utilizing within row cultivation and reduced rates of postemergence herbicides. Weed Sci. Soc. Am. 33:5.

VanGessel, M.J., Wiles, L.J., Schweizer, E.E. and Westra, P. 1993. Dry bean injury from pre-cultivation tillage. West. Soc. Weed Sci. p. III-43.

Wiles, L.J., Oliver, G.W., York, A.C., Gold, H.J., and Wilkerson, G.G. 1992. Spatial distribution of weeds in North Carolina soybean (*Glycine max*) fields. Weed Sci. 40:554-557.

Wiles, L.J., Wilkerson, G.G., Gold, H.J., and Coble, H.D. 1992. Modeling weed distribution for improved postemergence control decisions. Weed Sci. 40:546-553.

Wiles, L.J., Gold, H.J., and Wilkerson, G.G. 1993. Modelling the uncertainty of weed density estimates to improve post-emergence herbicide control decisions. Weed Res. 33:241-252.

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[illegible], [illegible] and [illegible]. 1991. [illegible] In: Agricultural Research to Protect Water Quality. Soil and Water Conservation Society. [illegible]

[illegible], [illegible] and Wiatrak, P. 1993. [illegible] In: [illegible] 15:[illegible]

[illegible] 1993. [illegible] Modeling Geo-Biosphere Processes. [illegible]

[illegible] 1992. [illegible] Modeling Geo-Biosphere Processes. [illegible]

[illegible] 1993. [illegible] Water Resources Research. [illegible]

[illegible] and Wiatrak P. [illegible] Weed Sci. [illegible]

[illegible] 1995. Weed control [illegible] Weed Sci. [illegible]

[illegible] 1995. Weed [illegible] Weed Sci. [illegible]

[illegible] 1996. [illegible] Weed Sci. [illegible]

[illegible] 1992. [illegible] Weed Sci. 40:[illegible]

[illegible] 1993. Modeling [illegible] Weed Sci. [illegible]

[illegible] 1997. Modelling the [illegible] Weed Res. [illegible]